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CATEGORY II PROPULSION SYSTEM EVALUATION

CATHARST
Propulsion Engineer

EDWARD ... LL

TECHNICAL REPORT NO. 71-

AUGUST 1971

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AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

BEST AVAILABLE COPY

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS DIVISION (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: ASD/SDQH 1-88 (Maj Thompson/rb/54440/R&D 13-2-3/UH-1N)

SUBJECT: ASD Addendum Report to FTC-TR-71-39

26 Jan 72

TO: Recipients of FTC-TR-71-39

This report is a part of and should remain attached to FTC-TR-71-39. Paragraph numbers below correspond to recommendations in FTC-TR-71-39.

1. Concur with intent. Actions resulting from AFPE test report are continuing, as outlined in ASD Supplemental Report to FTC-TR-70-22, dated 15 Oct 71.

2. Concur with intent. Investigative and corrective actions which began with the receipt of the UMR's will be completed according to normal procedures.

3. Do not concur. Leaving the switch off will preclude damage to the system if a malfunction occurs during engine start. This recommendation will be presented for discussion at the next flight manual command review.

4. Do not concur. For information, airframe ECP #566 is in process to have the generator caution light remind the pilot to neutralize the switch in accordance with flight manual procedures. Hazard of starter drive overheat is considered improbable, as current is not expected to exceed 25-30 amperes at 12,000 rpm. The discrepancy does not merit further redesign effort as recommended. Costs associated with the recommended change are not commensurate with anticipated benefit.

5. Concur with intent. ASD has initiated action to incorporate the required information in the appropriate aircraft manuals.

6. Concur with intent. ASD has initiated action to incorporate the required information in the appropriate aircraft manuals.

7. Do not concur. No adverse comments on these switches have been received from any operator. Configuration was acceptable during formal cockpit mock-up.

8. Concur with intent. Abrupt movement of flight controls is prohibited by section V of the flight manual. No further action is planned.

9. Do not concur. Costs associated with the recommended change are not commensurate with the anticipated benefits. Flight manual coverage of this characteristic should suffice. ASD has initiated action to incorporate the required information in the flight manual.

10. Do not concur. Frequency of this occurence is rare. The cited overspeed amounted to less than 1/3 of 1%. Costs associated with this change are not commensurate with the benefit to be derived.

11. Concur with intent. Study is in progress both by ASD Engineering and the engine contractor. Redesign will be considered upon completion of investigation

12. Concur with intent. Engine performance data in the flight manual is in the form of Power Assurance Check for operational "go, no-go" decisions. Topping information is available in T.O. 1H-1(U)N-6CF-1 and provides estimated power available from a properly topped power section. All estimated data is being updated as information becomes available. Upon receipt of substantiated data from performance test in progress, ASD will completely revise the data "estimated" to "AF Flight Test" in all appropriate aircraft manuals.

13. Concur with intent. Procedures for monitoring power deterioration in flight will be developed during follow-on testing. Power assurance check has been provided in the flight manual for operational "go, no-go" decisions.

14. Concur with intent. ASD is taking action to eliminate T_5 limiter function from UH-1N. Deactivation will be by WRAMA TCTO: removal will follow.

15. Concur with intent. However, due to austere funding of UH-1N Programs, the existing Army UH-1H fuel tank configuration was used. Recommendation should be considered in future procurements, if applicable.

16. Concur with intent. BHC-ECP-525 was disapproved because it was considered beyond scope of this program. For information, even a small increase in the empty weight would incur a serious performance penalty for the aircraft mission performance. This recommendation must be considered with the possibility of raising the system gross weight limit to 11,500 pounds and increasing the internal fuel capacity by 100 gallons in order to avoid degrading UH-1N performance below that of the UH-1F. Costs associated with modification of this magnitude would be prohibitive. Further action is withheld pending receipt of substantiated user requirements.

17. GENERAL COMMENT. The oil system description contained on page 40 of report erroneously identifies the power source for the oil cooler fans. For information, the UH-1N cooler fans are shaft powered by the engine.

FOR THE COMMANDER

William D Eastman Jr

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FTC-TR-71-39

UH-1N
CATEGORY II PROPULSION SYSTEM EVALUATION

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FOREWORD

The UH-1N Category II systems evaluation program began on 18 October 1970 and was still in progress at the time this report was prepared. This report presents operational analysis, systems evaluations, and aerospace ground equipment evaluations for the propulsion system. The test program was conducted under the authority of AFR 80-14 and was requested by ASD (ASZTH) letter, subject "UH-1N Category II Testing by AFFTC", dated 21 August 1969. It was authorized by AFFTC Project Directive 69-49, dated 20 February 1969, and Program Structure 443N.

The authors express their appreciation to Edwin A. Kowal, Captain, USAF, for his contributions to the program as technical observer and instrumentation operator during the test flights, and as an engineering assistant during the data reduction and analysis portion of the program.

Foreign announcement and dissemination by the Defense Documentation Center are not authorized because of technology restrictions of the U.S. Export Control Act as implemented by AFR 400-10.

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ABSTRACT

This report presents the results of the propulsion system evaluation conducted during the UH-1N Category II systems evaluation program. The propulsion system was adequate for accomplishment of mission objectives, but several improvements should be made. Flight Manual changes were considered necessary for engine starting, manual fuel control operation, engine topping parameters, and engine deterioration. Rotor overspeed occurred when the beep switch was actuated to increase rotor speed and when the collective pitch control was lowered. The fuel system should be redesigned to provide tank isolation in the event of combat damage. The fuel system should also be crashworthy. Operation, functional adequacy, accessibility, and ease of servicing of the drive and transmission components were acceptable.

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list of abbreviations

Item	Definition
AFPE	Air Force Preliminary Evaluation
AGE	aerospace ground equipment
Batt	battery
Gen	generator
ITT	interturbine temperature (deg C)
KIAS	knots indicated airspeed (kt)
N_f	power turbine speed (rpm)
N_g	gas generator compressor speed (rpm)
N_R	rotor speed (rpm)
PA	pressure altitude (ft)
SOAP	Spectrometric Oil Analysis Program
SPO	System Program Office
UMR	Unsatisfactory Materiel Report

INTRODUCTION

This report presents the results of the UH-1N Category II propulsion system evaluation conducted at the Air Force Flight Test Center, Edwards AFB, California. A total of 6.4 hours of propulsion system evaluation time was spent on UH-1N S/N 69-6610, and 16.0 hours were spent on aircraft S/N 68-10776. This evaluation was a part of the Category II systems evaluation program which was initiated on 18 October 1970. The AFFTC was responsible for the conduct of the program under the jurisdiction of the UH-1N System Program Office (SPO), Wright-Patterson AFB, Ohio.

One aircraft, S/N 69-6610, was assigned for the duration of the program. However, the Category II performance and flying qualities aircraft, S/N 68-10776, was used for the majority of the tests reported herein because necessary instrumentation was available on that aircraft and not on aircraft S/N 69-6610.

Portions of the propulsion system tests outlined in appendix A-1 of the UH-1N Category II Systems Test Plan (reference 1) are not presented in this report. Data for these tests will be gathered on the all-weather test aircraft, S/N 68-10774, and will be presented in the final reports covering the climatic phase of the Category II program. These tests include:

I.G.[1]	Prolonged engine operation
II.B.5	Fuel system temperatures
II.B.7	Oil consumption rate
III.B.1	Transmission oil temperature and pressure
III.B.4	Oil cooling systems

This report summarizes propulsion system test results presented in monthly progress reports submitted through 5 July 1971. Information obtained and/or finalized after that date is presented for the first time in this report. Results of tests on other UH-1N subsystems are presented in references 2 and 3.

[1] Paragraph numbers refer to those contained in appendix A-1 of reference 1.

PROGRAM OBJECTIVES

The objectives as stated in the published test plan, reference 1, were to:

1. Fly the aircraft throughout its service envelope and evaluate it under both normal and simulated partial failure conditions.

2. Determine the functional adequacy and the limits of performance of each subsystem.

3. Comply with the objectives set forth in Section 5, Part b, of AFR 80-14, dated 24 February 1967.

AIRCRAFT DESCRIPTION

The UH-1N utility helicopter was manufactured by the Bell Helicopter Company. It was capable of operating from prepared or unprepared takeoff and landing sites, under visual or instrument flight conditions, day or night. It utilized the basic UH-1D airframe with a modified fuselage nose and engine cowlings. The dynamic components were similar to those of a UH-1D except for an uprated main transmission (1,250 shaft horsepower), new thin tip rotor blades, a tractor-type tail rotor, and installation of the twin engines with a combining gearbox. The helicopter was powered by a T400-CP-400 turboshaft engine (1,800 shaft horsepower at sea level, static, uninstalled conditions). The engine consisted of two independent power sections driving into a combining gearbox. The maximum gross weight was increased from 9,000 pounds to 10,000 pounds (9,500 to 10,500 pounds for the external cargo configuration). The aircraft could be armed with a 7.62mm minigun, a 40mm grenade launcher, and a 2.75-inch folding fin rocket system. A detailed description of the aircraft was given in T.O. 1H-1(U)N-1, reference 4.

The primary mission of the aircraft, called the Special Operations Forces mission, was counterinsurgency, unconventional warfare, and psychological warfare operation. The alternate mission of the aircraft was to provide air support in the areas of logistics, airfield security, and personnel transport. In addition, the aircraft could be used for medical evacuation and ambulance service.

Aircraft S/N 69-6610 was equipped with left-hand engine S/N 66011, right-hand engine S/N 66012, and combining gearbox S/N 4006. Aircraft S/N 68-10776 was equipped with left-hand engine S/N 66127, right-hand engine S/N 66128, and a combining gearbox S/N 4046.

TEST AND EVALUATION

GENERAL

Several aspects of the propulsion system were evaluated during the Air Force Preliminary Evaluation (AFPE) held at the contractor's facility between 10 and 27 July 1970, and were reported on in FTC-TR-70-22 (reference 5). Items that were adequately evaluated during the AFPE were not retested during the Category II Program. These were:

1. Ground starts using the manual fuel control.

2. Flight using the manual fuel control on one engine and on both engines.

3. Compressor inlet temperature excursions due to bleed air discharge.

The recommendations developed during the AFPE that were still outstanding as of the date of this report were reviewed. These recommendations were still considered valid and should be implemented. **(R 1)**[2]

All unsatisfactory materiel reports (UMR's) are listed in appendix I with their last known action status. Additional information on action status can be obtained from the UH-1N SPO. The UMR's were submitted in accordance with T.O. 00-35D-54 (reference 6). The specific recommendations included in each UMR are not repeated in the Conclusions and Recommendations section. Those deficiencies documented in UMR's that are still open for action should be corrected. **(R 2)**

Evaluations of AGE were conducted during normal usage. Specific tests were not conducted; however, usage was monitored by engineering personnel. Interviews were held with maintenance personnel to determine the adequacy of the AGE from a user's standpoint.

INSTRUMENTATION

Aircraft S/N 69-6610 contained no special instrumentation applicable to the propulsion system evaluation. Data obtained during tests on that aircraft were recorded from the standard cockpit instruments. Aircraft S/N 68-10776 was instrumented primarily for performance and flying qualities evaluations. Numerous engine parameters included were utilized for the evaluations reported herein.

The instrumentation installed in aircraft S/N 68-10776 consisted primarily of a 50-channel oscillograph, a photopanel, a time correlation system, appropriate mechanical/electrical sensors, and associated wiring and controls. The oscillograph contained only two parameters directly applicable to the propulsion system evaluation, collective pitch control

[2]Boldface numerals preceded by an R correspond to the recommendation numbers tabulated in the Conclusions and Recommendations of this report.

position and both engine throttle positions. The photopanel was used to record the remainder of the engine parameters and the flight conditions presented in this report.

A time correlation intervalometer was used to actuate a counter device in the oscillograph and the photopanel. A second intervalometer was used to actuate the photopanel camera. Since these intervalometers were not synchronized, data correlation between the oscillograph and photopanel could be accomplished only to the nearest second of time. As a consequence, collective pitch control and the throttle positions presented herein are correlated to the engine parameters only to within one second.

Each of the following sections contains a brief subsystem description, specific test objectives, specific ground and flight tests, and evaluation of AGE as applicable.

POWER PLANT

General

System Description.

The twin power package (T400-CP-400) consisted of two engines (PT6T-4) and a combining gearbox. Each gas turbine engine had an uninstalled rating of 900 shaft horsepower at sea level, standard day conditions. An engine-air particle separator and an ice detection system were provided. The combining gearbox accepted power from the engines, reduced the power turbine speed (N_f) to 6,600 rpm (100 percent N_f), and delivered the power through a common output. Torque on each engine was measured by means of a hydromechanical torquemeter using oil pressure. Overrunning clutches in the two drives into the output section allowed engine torque to be transmitted in one direction only, thus providing for both single-engine operation and two-engine-out autorotation. Load sharing between the engines was accomplished by an automatic torque-matching device which compared the torquemeter oil pressures of the two engines and automatically adjusted the power of the individual engines to equalize their torque outputs. A rotor speed (N_R) droop compensating system compensated for the power turbine governor droop. A detailed description of the system was given in reference 4.

Test Objectives.

Specific test objectives were:

1. To determine the ground starting characteristics of the engine using the automatic fuel control.

2. To determine the altitude/airspeed envelope for airstarting the engine.

3. To determine the acceleration and deceleration characteristics of the engine and rotor system.

4. To determine the effects of simulated single-engine failure.

5. To monitor the spectrometric oil analysis program (SOAP).

6. To determine the effects of compressor bleed air extraction on engine parameters.

7. To determine the functional adequacy of the manual fuel control.

Ground Tests

Engine Starts.

Test Description

All engine starts performed during the test program were monitored by the pilots to assure conformance to Flight Manual limits. A series of starts was performed in which one engine was started on the battery, and the second engine was started using generator power from the operating engine. These starts were performed per Flight Manual procedures using the automatic fuel control. Engines using battery and generator power were alternated, left and right, on consecutive flights.

Functional Analysis

Table I presents data obtained during the specific ground test series. Engine starts using the battery as the power source typically exhibited higher interturbine temperatures (ITT's) than those using generator power. Pilot technique used during the starting procedure (manually controlling fuel flow with the throttle between the cut-off position and the ground idle position) resulted in wide variation of maximum ITT's experienced. In no case did the ITT approach the maximum allowable transient limit of 870 degrees C. All battery starts were also characterized by ammeter readings up to 300 amperes for durations up to 35 seconds. Although these readings were on the red line, no detrimental effects were noted. Ground starts using either battery power or generator power were satisfactory.

Operational Analysis

Engine starting was trouble-free and required a very low workload. At the ambient temperatures experienced during this program, engine acceleration from the time of starter engagement was excellent. Engine light-off occurred within three to five seconds after fuel was introduced into the engine with the throttle. Engine acceleration was then smooth throughout the remainder of the start sequence. Total time to start each engine was approximately 20 seconds.

Table I

ENGINE GROUND START TEST SUMMARY
Automatic Fuel Control

Left Engine		Right Engine		Outside Air Temp (deg C)	Wind	
Power	Max ITT (deg C)	Power	Max ITT (deg C)		Velocity (kt)	Direction to Aircraft
Gen	590	Batt	720	35	14	Left
Batt	755	Gen	560	23	10	Left rear
Gen	585	Batt	700	32	20	Left front
Gen	625	Batt	703	23	10	Left rear
Batt	728	Gen	522	22	5	Left front
Batt	750	Gen	515	19	0	- - -
Gen	520	Batt	685	13	6	Left rear
Batt	725	Gen	488	20	5	Left
Gen	600	Batt	685	15	12	Left rear
Batt	728	Gen	510	17	8	Left rear
Batt	740	Gen	530	15	6	Front
Gen	550	Batt	710	24	8	Left
Gen	550	Batt	760	28	10	Rear
Batt	660	Gen	610	20	20	Rear
Batt	750	Gen	570	40	10	Rear

Spectrometric Oil Analysis.

Test Description

Spectrometric oil sampling and analysis were performed according to T.O. 42B2-1-9 (reference 7) for each engine and the combining gearbox at the end of each day's flying in order to continually monitor power plant condition. Oil samples were sent to SMAMA (SMMQQLB), McClellan AFB, California, for analysis.

Functional Analysis

Since reference 7 required the oil analyzing agency to report to the oil submitting agency only those samples exceeding specification limits, no data were available on metallic content or trends established during the program. Details on these data may be obtained from the above address. The SOAP did not reveal any discrepancies in any of the engines used.

Flight Tests

Engine Airstarts.

Test Description

A comprehensive program of 35 airstarts was conducted within the flight envelope of the UH-1N. Two types of airstart procedures were used during the test program. At the beginning of the program, the procedure outlined in the basic Flight Manual was used, in which the starter was engaged and the throttle was advanced to the flight idle position when 12-percent gas generator speed (N_g) was achieved. During the program, Flight Supplement T.O. 1H-1(U)N-1SS-1 (reference 8) was received. It modified the start procedure to require that the throttle be modulated between cutoff and the flight idle position in order to permit some pilot control of ITT during the start cycle. Tests performed using these two procedures are shown in table II. Various combinations of system modes were evaluated including automatic and manual fuel control, generator and battery electrical power, as shown in table II.

Functional Analysis

Table II presents the maximum ITT's observed during all the airstarts performed. Figure 1 presents the data points evaluated in relation to the flight envelope. Maximum ITT's were generally lower when the airstart was performed using the Flight Supplement procedure. Airstarts performed using the battery as the electrical power source exhibited higher ITT's than those performed using generator power. In general, a wide variation in maximum ITT's was observed when the Flight Supplement procedure was used because of the effect of pilot technique. The maximum ITT's observed on the tests were all well below the maximum allowable transient of 870 degrees C. Engine airstarts performed in various system modes throughout the flight envelope were satisfactory.

Operational Analysis

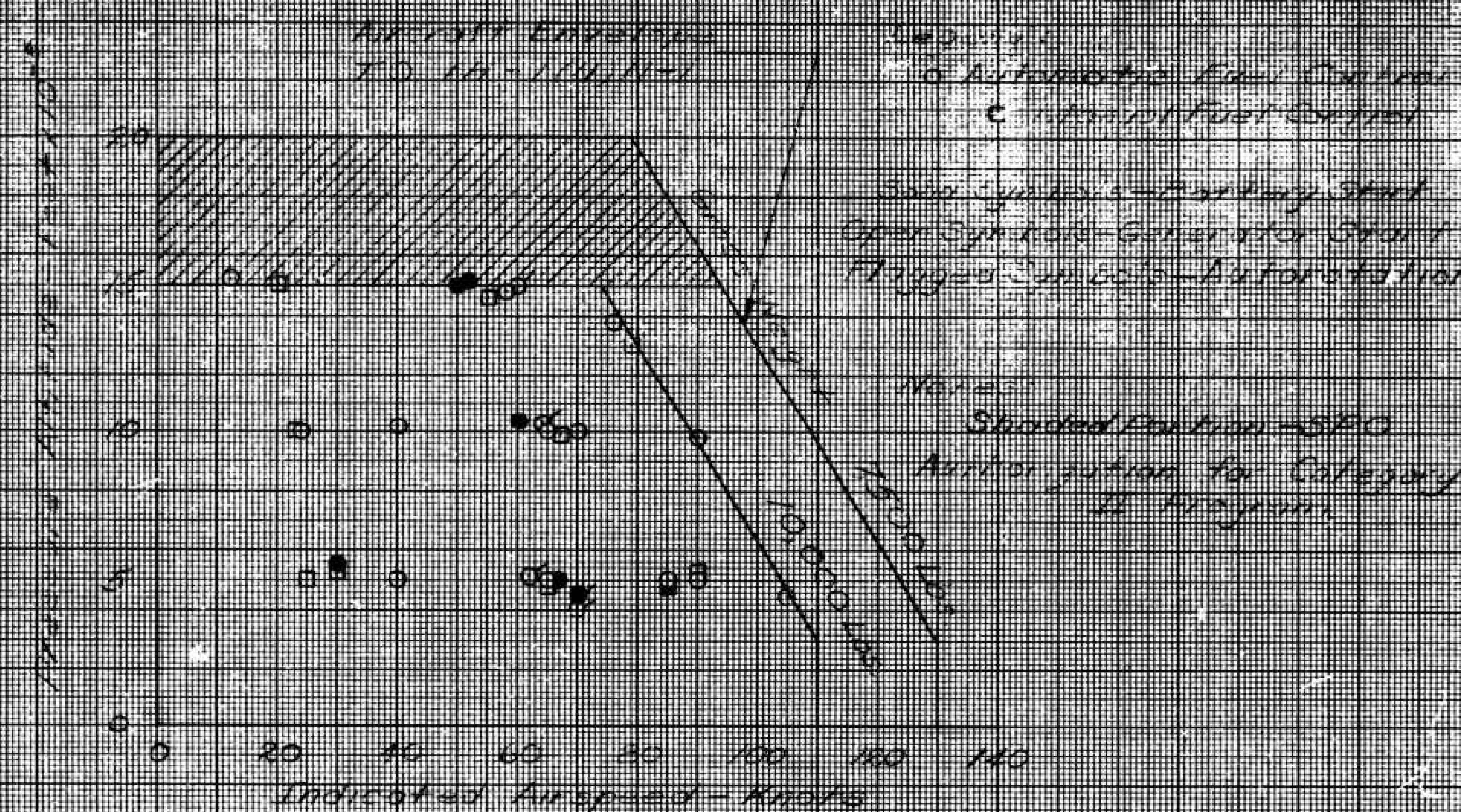
There was apparently no engine air inlet ram effect at any flight condition tested. Consequently, no engine windmilling was noted and air start characteristics were essentially the same as those of ground starts. Airstarts were therefore no more difficult than ground starts except for the pilot workload and distraction involved with flying the aircraft at the same time. All airstarts were performed as described above and presented no unusual problems from a pilot standpoint.

Table II

AIRSTART TEST CONDITIONS AND RESULTS

Test Conditions					Results
Pressure Altitude (ft)	Airspeed (KIAS)	Fuel Control	Start Power	Flight Condition	Max ITT (deg C)
4,000	70	Auto	Gen	Autorotation	620
4,500	105	Auto	Gen	Level	600
4,500*	70	Auto	Batt	Autorotation	640
4,950	25	Man	Gen	Level	590
5,000*	40	Auto	Gen	Level	760
5,000*	65	Auto	Gen	Level	600
5,000*	65	Auto	Gen	Level	710
5,000*	85	Auto	Gen	Level	620
5,000	70	Auto	Gen	Level	520
5,000	85	Man	Batt	Level	680
5,000*	65	Auto	Batt	Level	800
5,000*	65	Man	Gen	Level	710
5,100	62	Auto	Gen	Autorotation	590
5,160	65	Man	Gen	Level	570
5,200	90	Man	Gen	Level	510
5,200	30	Man	Gen	Level	640
5,500*	30	Auto	Batt	Level	680
9,850	90	Auto	Gen	Level	520
9,900	67	Man	Gen	Level	690
10,000	65	Auto	Gen	Level	520
10,000	70	Auto	Gen	Level	520
10,000	24	Auto	Gen	Level	500
10,000	23	Man	Gen	Level	690
10,180	40	Auto	Gen	Level	540
10,300	60	Auto	Batt	Level	700
10,300	64	Auto	Gen	Autorotation	496
13,000	79	Man	Gen	Level	810
13,800	76	Auto	Gen	Level	680
14,600	55	Man	Gen	Level	650
14,800	58	Auto	Gen	Level	650
15,000	50	Auto	Batt	Level	700
15,000	60	Auto	Gen	Autorotation	590
15,100	20	Man	Gen	Level	640
15,200	52	Auto	Batt	Level	720
15,200	12	Auto	Gen	Level	520

*These tests were performed by advancing the throttle directly to IDLE per basic Flight Manual procedures. All others were performed using Flight Supplement T.O. 1H-1(U)N-1SS-1 procedures.



AIR START SUMMARY

Figure 1

The Flight Manual airstart checklist required that the generator switches be placed in OFF prior to engaging the starter switch. Activation of the starter switch automatically put the starter/generator in the starter mode and deactivated the generator function. The process of turning the generator switch to OFF produced a needless switch action. The Flight Manual should be revised to delete the required action of turning the generator switch to OFF prior to engine start. **(R 3)**

During the engine start sequence, manual deactivation of the starter switch at 50-percent N_g speed was frequently omitted. The chance of failing to disengage the starter was made more probable by the function of the dc generator warning circuit because the DC GENERATOR caution light was extinguished anytime that the starter was engaged. Failure to disengage the starter could result in starter drive overheating, and possible fire. The starter switch should be redesigned to incorporate an automatic deactivation feature. **(R 4)**

Fuel Control Switchovers.

Test Description

Fuel control switchover tests from automatic to manual and back to automatic were accomplished at the test conditions shown in table III. These tests were conducted to evaluate the function of the manual fuel control switchover valve and the transient functions of the engine during and after switchover. Test procedures were as follows:

1. The aircraft was stabilized at the test airspeed and altitude with the test engine at flight idle in the automatic fuel control mode.

2. Data were recorded.

3. Manual fuel control was selected on the test engine and the system was allowed to stabilize for at least 30 seconds.

4. Data were recorded.

5. Automatic fuel control was reselected on the test engine and the system was allowed to stabilize for at least 30 seconds.

6. Data were recorded.

Functional Analysis

Test results are presented in table III. Gas generator speed and ITT were consistently higher in manual fuel control than in automatic fuel control. The difference increased in magnitude as altitude increased. At 20,000 feet pressure altitude (PA), N_g idle speed was 82-percent rpm in manual fuel control compared to 73-percent rpm in automatic. This condition is normal for most back-up fuel control systems. No problems were encountered with the manual fuel control, and operation of this system was considered satisfactory.

Table III

FUEL CONTROL SWITCHOVER TESTS

Test Conditions			Results	
Pressure Altitude (ft)	Airspeed (KIAS)	Fuel Control	ITT (deg C)	N_g (pct)
5,100	25	Auto Man Auto	480 490 470	63 69 63
4,700	30	Auto Man Auto	460 505 480	60 61 67
5,000	50	Auto Man Auto	475 490 475	62 69 64
4,920	66	Auto Man Auto	458 500 445	60 61 61
4,900	100	Auto Man Auto	475 480 460	62 69 63
10,000	24	Auto Man Auto	475 500 480	64 74 64
10,000	55	Auto Man Auto	460 495 460	63 64 63
9,820	61	Auto Man Auto	465 488 465	60 67 58
10,100	90	Auto Man Auto	480 500 460	63 74 63
15,000	17	Auto Man Auto	465 500 ---	67 78 --
14,650	55	Auto Man Auto	500 520 500	65 78 65
15,000	85	Auto Man Auto	500 520 500	64 77 64
20,200	60	Auto Man Auto	485 534 470	73 82 73

Operational Analysis

The Flight Manual contained no reference to expected N_g speed change when switching from automatic to manual fuel control. The Flight Manual should be revised to incorporate a NOTE similar to that contained in T.O. 1H-1(U)N-2-2 (reference 9) which stated that switchover from automatic to manual fuel control should result in a rise in N_g of 4 percent at sea level and 2 percent additional rpm for each 1,000 feet of pressure altitude increase. (R 5)

The engines exhibited a characteristic "blurp" noise when fuel control switchovers were accomplished. The Flight Manual should be revised to incorporate a NOTE that this noise is normal. (R 6)

The close proximity of the FUEL CONT switches to other switches on the ENGINE AND FUEL CONTROL PANEL and indistinct labeling of the switches made fuel control switchovers disconcerting to the pilot. Some degree of N_f overspeed could be expected if switchover to MANUAL was erroneously accomplished on the engine operating at the flight required power load. The degree of overspeed could depend on existing power requirements and the pilot might not recognize the error in time to prevent a hazardous flight condition. To reduce switch confusion, the FUEL CONT switches should be labeled more clearly, preferably on top of the switch itself. (R 7)

Rotor Static Droop Characteristics.

Test Description

Rotor static droop characteristics in steady ground and flight conditions were evaluated with both engines operating concurrently, and with each of the left-hand and right-hand engines operating separately. These tests were performed to evaluate the capability of the power turbine governor to maintain rotor speed between normal power on limits of 314 to 324 rpm. Test procedures were as follows:

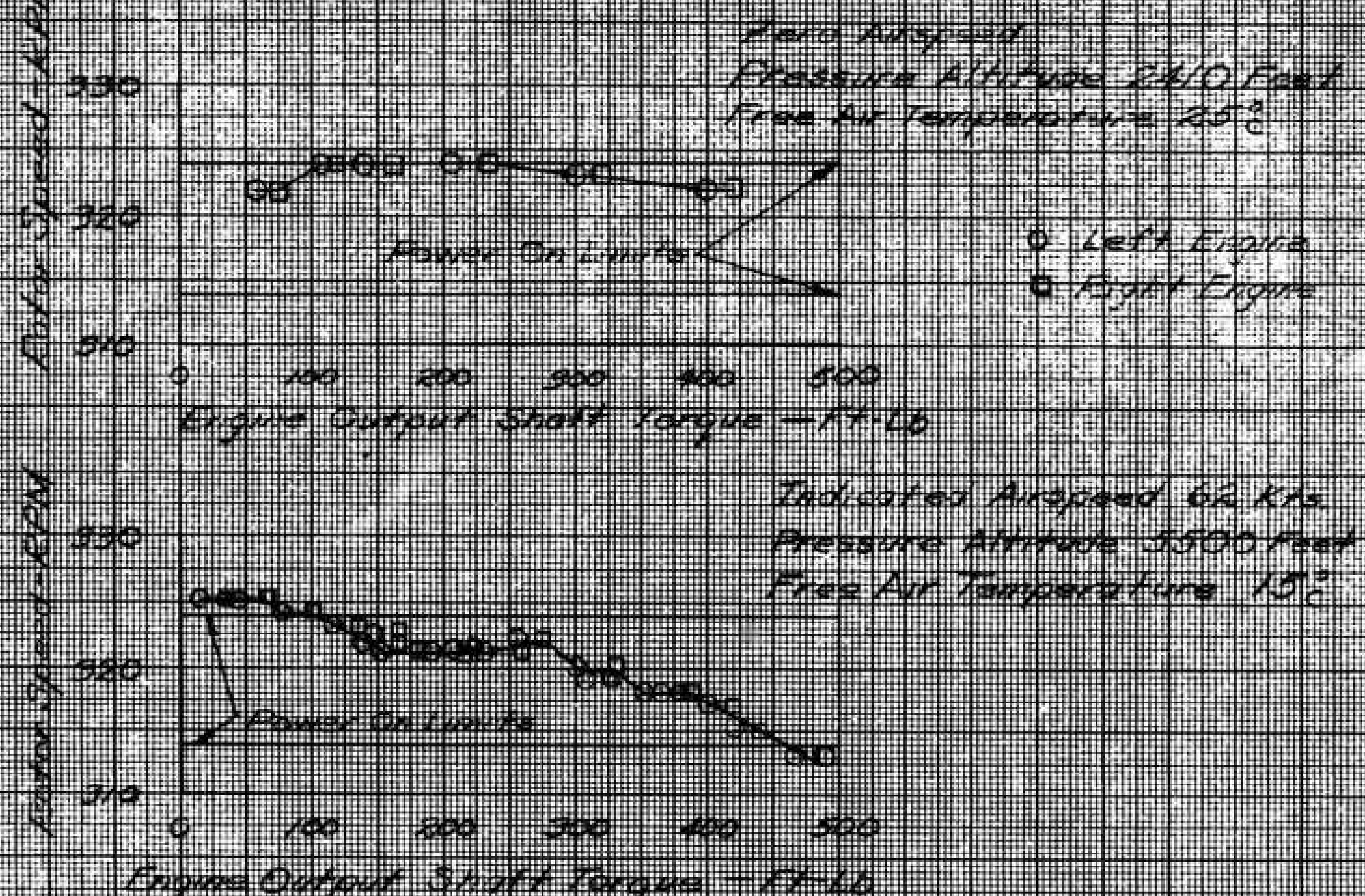
1. The aircraft was parked on the ground with both engines at full throttle and rotor speed adjusted to 324 rpm (100 percent). For the single-engine evaluation only one engine was at full throttle; the other was at idle.

2. Torque was increased in increments of approximately 10 percent until 100-percent torque was reached, or engine topping power was reached in the case of single engine operation. As takeoff power was obtained, a normal takeoff and climb were performed.

3. The aircraft was then climbed and stabilized in flight at 5,000 feet PA and 60 KIAS.

4. Torque was increased in 10-percent increments to 100 percent in the case of dual-engine operation, or until topping power was reached in the case of single-engine operation.

5. Torque was then decreased in 10-percent increments to minimum torque permissible without entering autorotation.



ROTOR STATIC DROOP DUAL-ENGINE

Figure 2

6. Torque was then increased in 10-percent increments to the level started at in item 3 above.

7. Data were recorded throughout the above maneuver. Each torque value was held at least 10 seconds to provide stabilized rotor speed and torque.

Functional Analysis

Dual engine static droop characteristics are shown in figure 2. During the ground run-up and takeoff, rotor speed stayed within two rpm without beep adjustment. Slight overcompensation occurred in the mid power range. This was a desirable feature because it helped to maintain a high rotor speed as a safety margin. At 5,000 feet PA, 62 KIAS, droop compensation was less ideal. Rotor speed gradually decayed with application of more power. Minimum rotor speed of 313 rpm was 1 rpm below minimum allowable power on limit of 314 rpm, but this was not considered significant. No hysteresis was apparent. Dual-engine static droop characteristics were considered acceptable.

Single-engine static droop characteristics are shown in figure 3. As expected, static droop of the single engine was approximately double that of the dual engine. Rotor speed drooped to 308 rpm above 550 foot-pounds torque at 2,400 feet PA and above 500 foot-pounds torque at 5,000 feet PA due to engine topping. Some slight mismatch occurred between the left and right engines due to different fuel control characteristics of the two engines. Single-engine static droop characteristics were considered acceptable.

Dual-Engine Transients - Collective Pitch Control.

Test Description

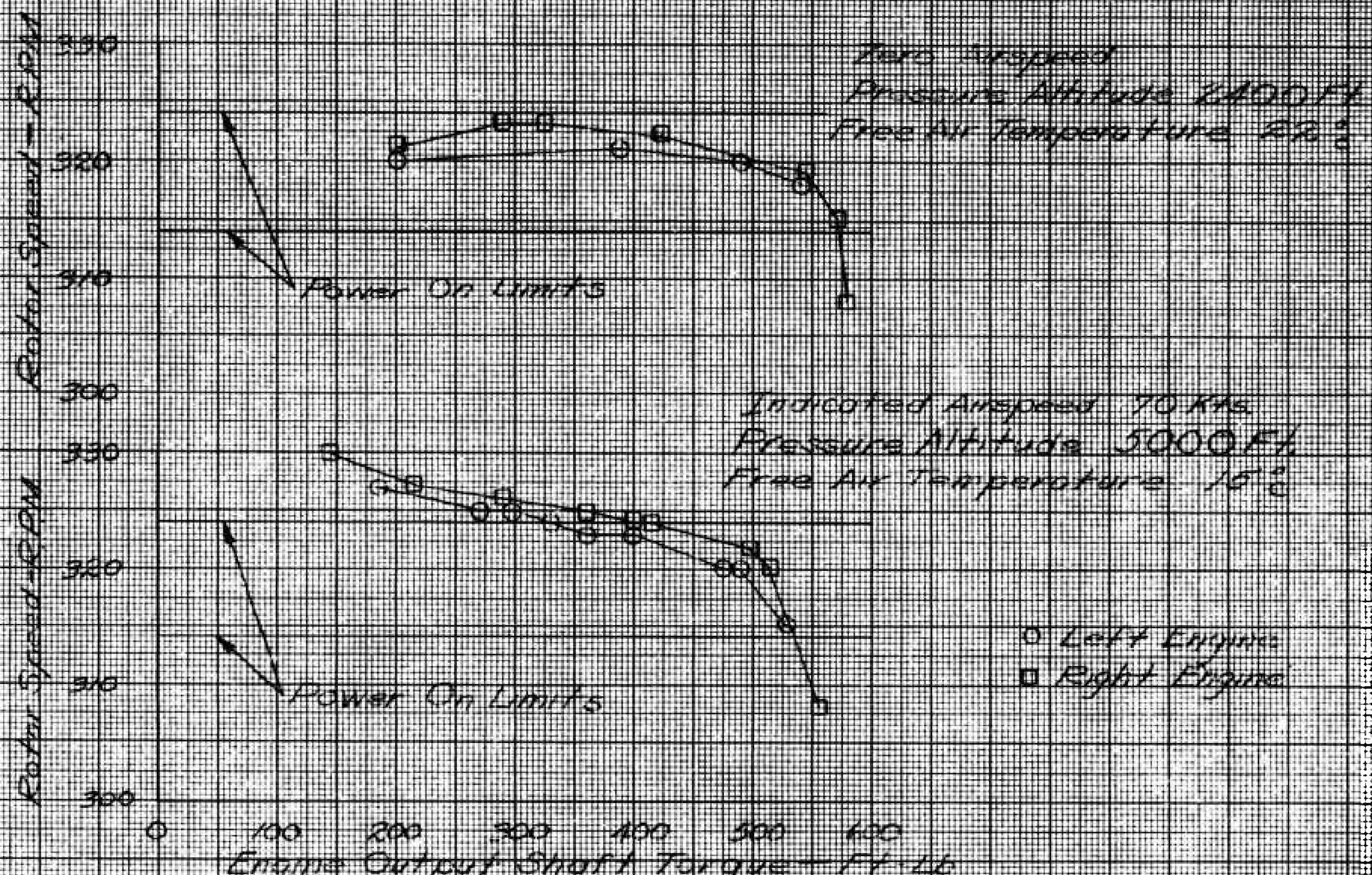
Dual-engine transients induced by lowering and raising the collective pitch control were performed at the test conditions shown in table IV. The test procedures were as follows:

1. The aircraft was stabilized in level flight at the test altitude and airspeed, and the rotor speed was adjusted to minimum beep, approximately 97-percent rpm. The beep switch provided N_f trim between approximately 97- and 102.5-percent rpm. The throttles were full open and torque was as required for level flight. The collective pitch control position was noted.

2. A fast rate of downward collective pitch control movement was used. However, the rate of movement was restricted to avoid rotor overspeed above the 104.5 percent rpm (339 rpm) maximum allowable transient limit.

3. The collective pitch control was raised at varying rates (approximately one to five seconds) to approximately the level started at in step 1 above. Propulsion system parameters were allowed to stabilize.

4. Data were recorded throughout the above maneuvers.



ROTOR STATIC DROOP SINGLE-ENGINE

Figure 3

Table IV

DUAL-ENGINE TRANSIENT - COLLECTIVE PITCH CONTROL

Pressure Altitude	Airspeed (KIAS)	Bleed Air Condition	Target Collective Movement Duration (sec)
4.470	25	ON	3
4,590	26	ON	1
4,860	29	OFF	1
4,900	30	OFF	3
4,940	69	OFF	2
4,970	34	ON	5
5,050	59	OFF	5
5,100	34	OFF	5
5,310	63	OFF	1
5,450	74	ON	1
5,500	64	OFF	1
8,530	10	ON	3
8,800	92	OFF	1
8,800	25	OFF	1
8,860	20	OFF	5
8,900	90	ON	1
8,930	15	ON	1
9,000	90	ON	5
9,000	90	OFF	5
9,000	20	ON	5
9,040	88	ON	3
9,050	92	OFF	3
9,050	26	OFF	3
9,350	62	ON	1
9,360	64	OFF	5
9,410	61	ON	3
9,480	55	ON	5
9,520	62	OFF	3
15,060	29	ON	1
15,280	30	ON	3
15,300	68	OFF	3
15,380	66	ON	1
15,420	32	ON	5
15,500	71	OFF	5
15,560	68	ON	3
15,700	73	ON	5
15,750	25	OFF	1
15,910	28	OFF	3
15,920	31	OFF	3

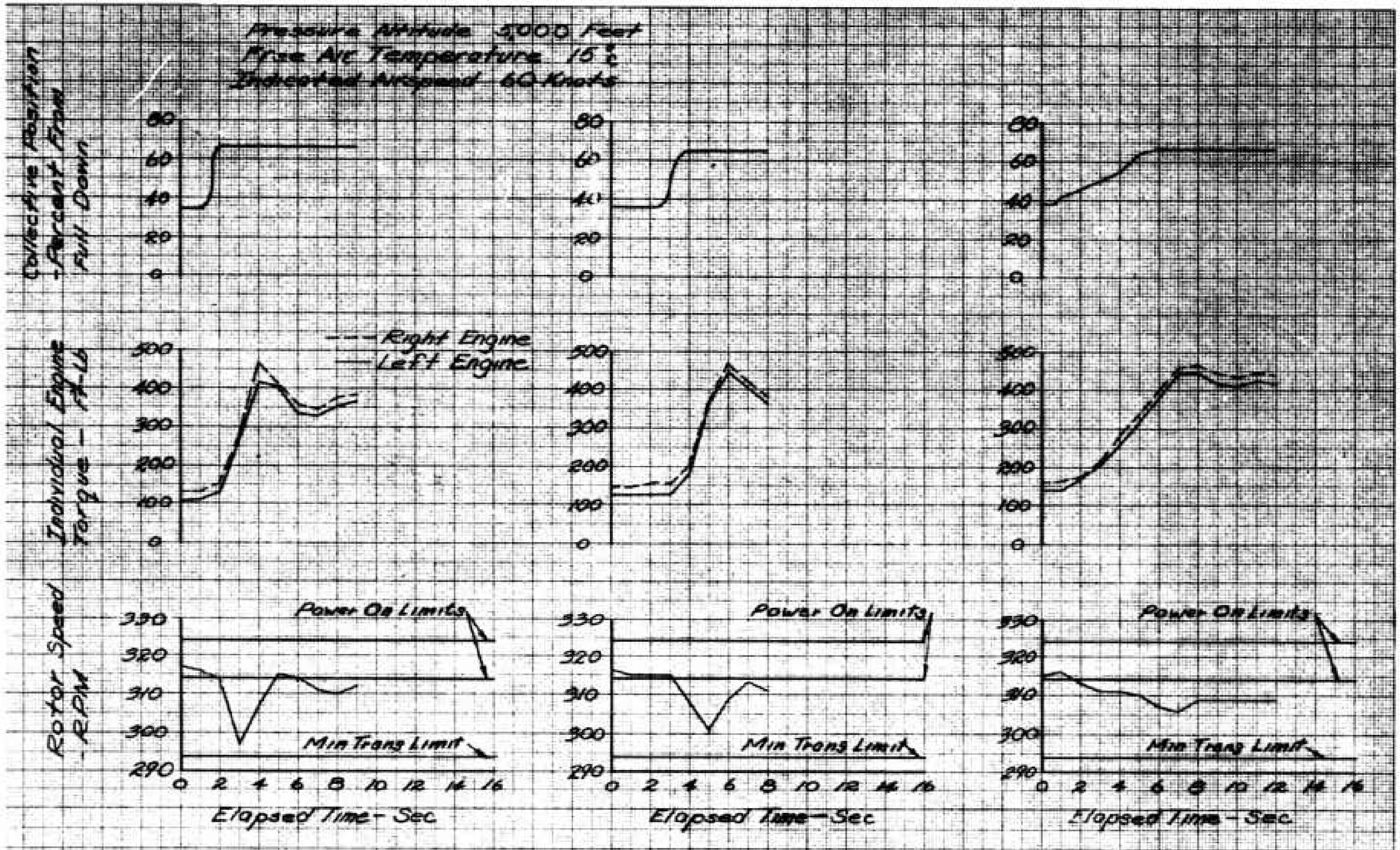
Functional Analysis

Figures 4 through 6 present time histories of N_R, engine torque, and collective pitch control position for some of the transients performed. Engine acceleration time and rotor droop recovery time were acceptable. No engine parameters approached specification limits during any of the transients and no compressor stall, rpm hangups, or ITT overtemperatures were experienced.

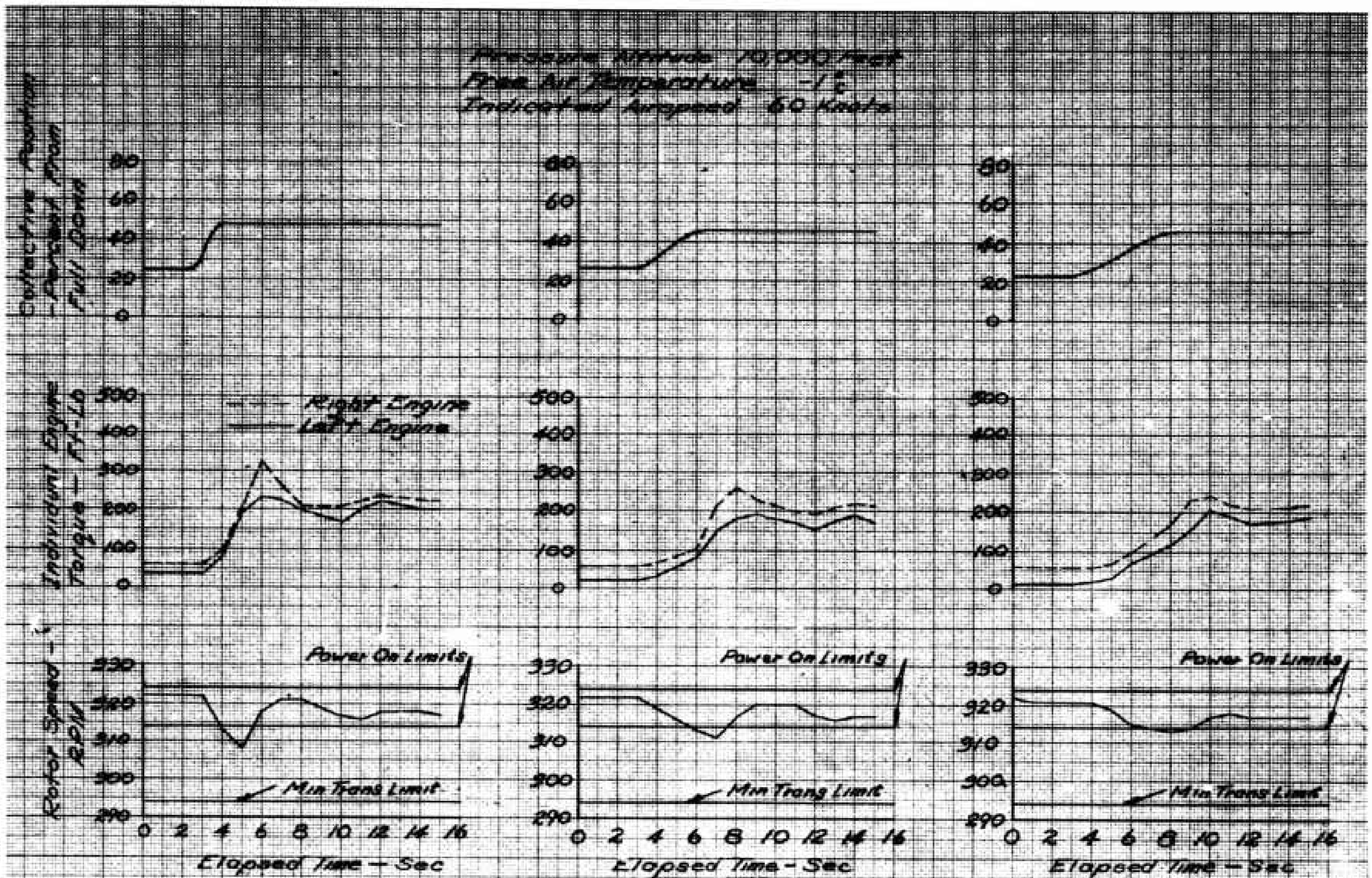
All transients exhibited a characteristic one cycle overshoot in torque and rotor rpm, with the overshoot more pronounced at the highest collective pitch control transients rates. This presented no problem during the testing. However, it was possible that the engines would overtorque if rapid collective pitch control movement to a high setting was attempted. A CAUTION should be added to the Flight Manual stating that this type of collective pitch control movement should be avoided. (R 8)

Figure 7 presents the relationship between torque demand rate and minimum transient rotor speed. Under no circumstances tested did rotor speed ever drop below the allowable minimum power-on transient speed of 294 rpm (91 percent). Data scatter shown on figure 7 was attributed to variations in pilot test technique and variations in rotor speed at the beginning of each test (321 to 327 rpm). In spite of these variations, the trend of lower minimum transient rotor speed with increased torque demand rate was clearly indicated. Engine acceleration and rotor droop characteristics during dual-engine transients induced by raising the collective pitch control were satisfactory.

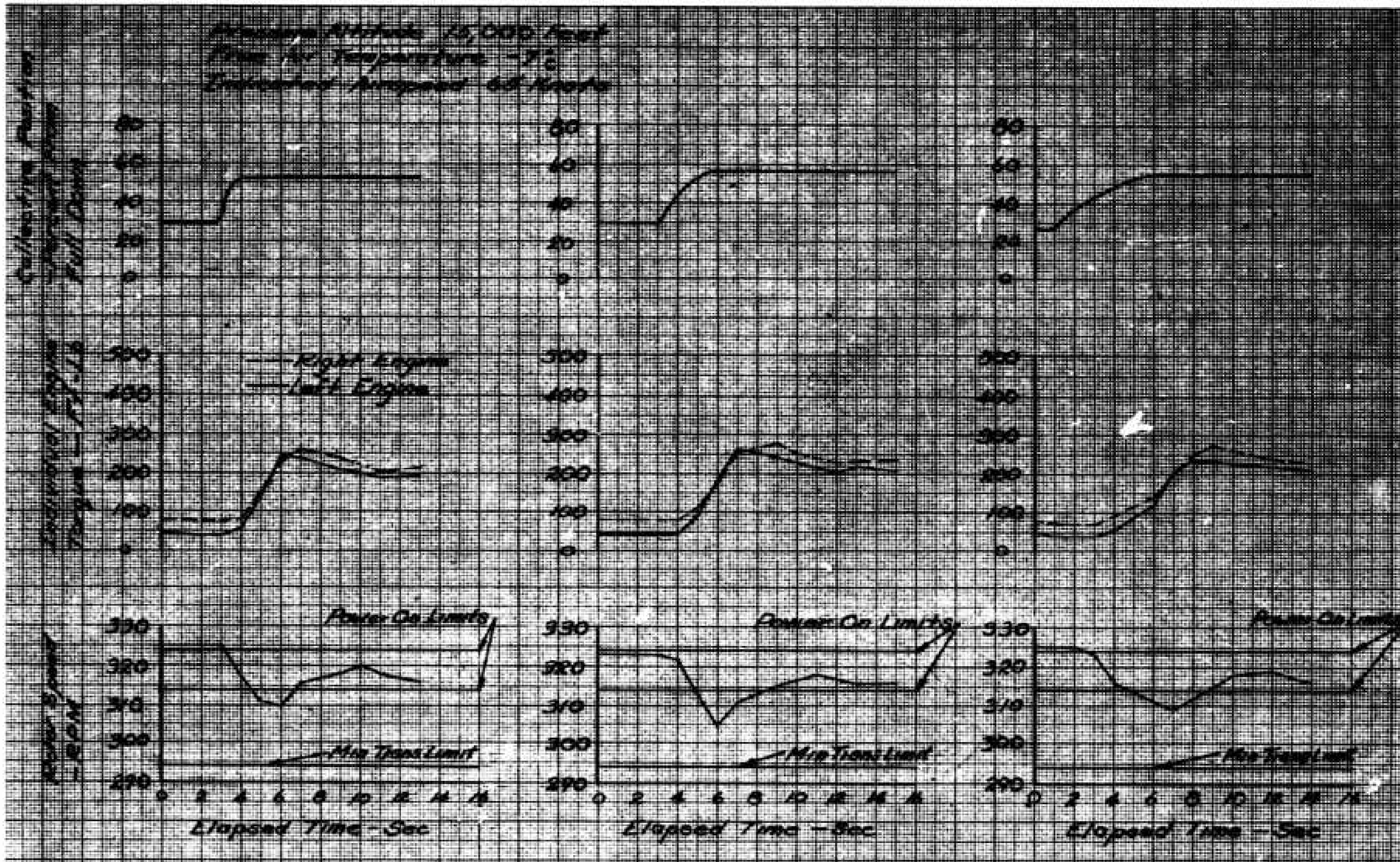
Figure 8 presents time histories of N_R, engine torque, and collective pitch control position for two typical engine transient tests in which the collective pitch control was lowered, first with minimum beep and then with maximum beep. In both cases rotor speed exceeded the power on limit of 324 rpm, even though the rate of collective pitch control movement was slow (5 and 9 seconds, respectively). Although not tested due to safety reasons, rotor speed could be expected to exceed even the maximum transient power-on limit of 338 rpm in the event the collective pitch control was lowered rapidly (one second or less) from a high power setting. These data indicate that rotor compensation characteristics were inadequate to maintain rotor speed within power-on limits even when minimum beep was applied. Rotor speed compensation should be improved to prevent rotor overspeed during engine transients induced by lowering of the collective pitch control. (R 9)



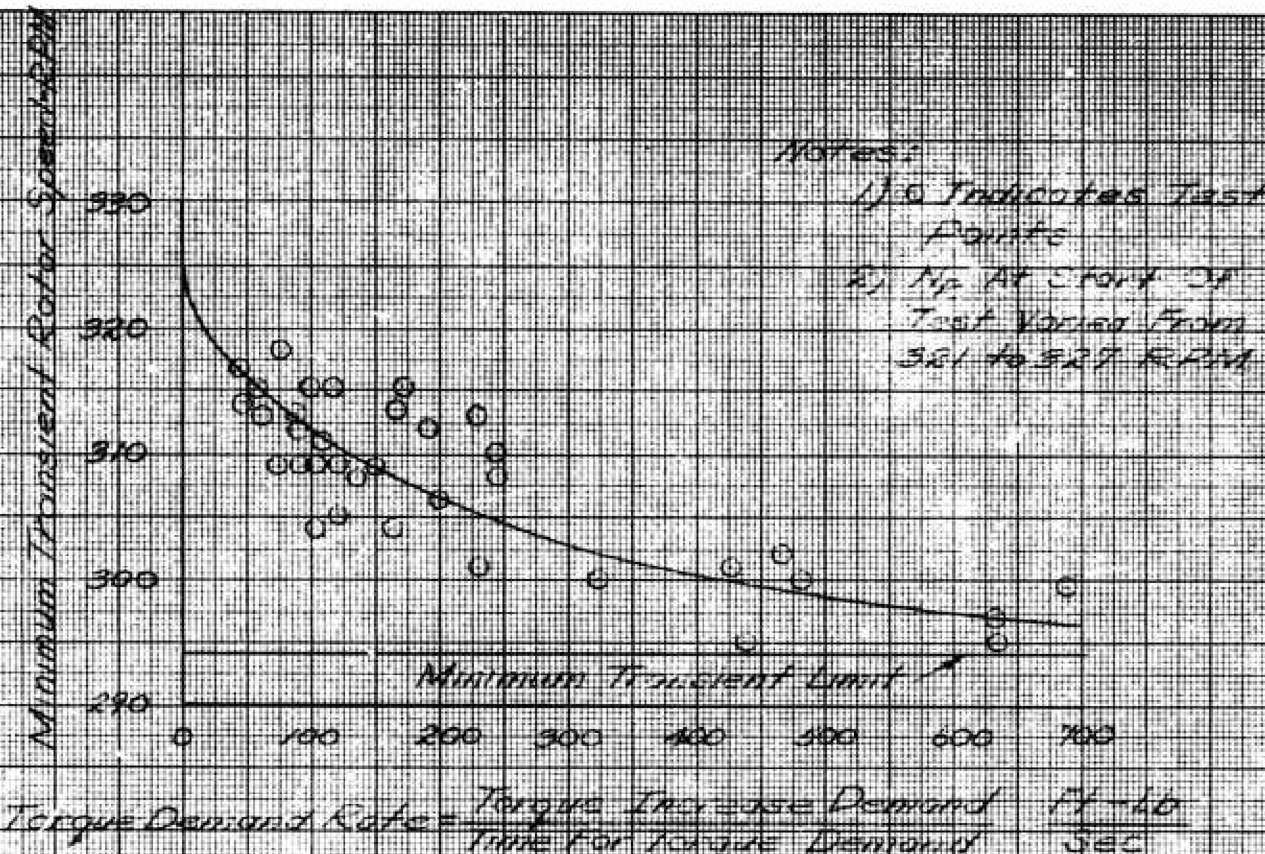
TIME HISTORIES OF DUAL-ENGINE TRANSIENTS -
COLLECTIVE PITCH CONTROL
Figure 4



TIME HISTORIES OF DUAL-ENGINE TRANSIENTS-
COLLECTIVE PITCH CONTROL
Figure 5

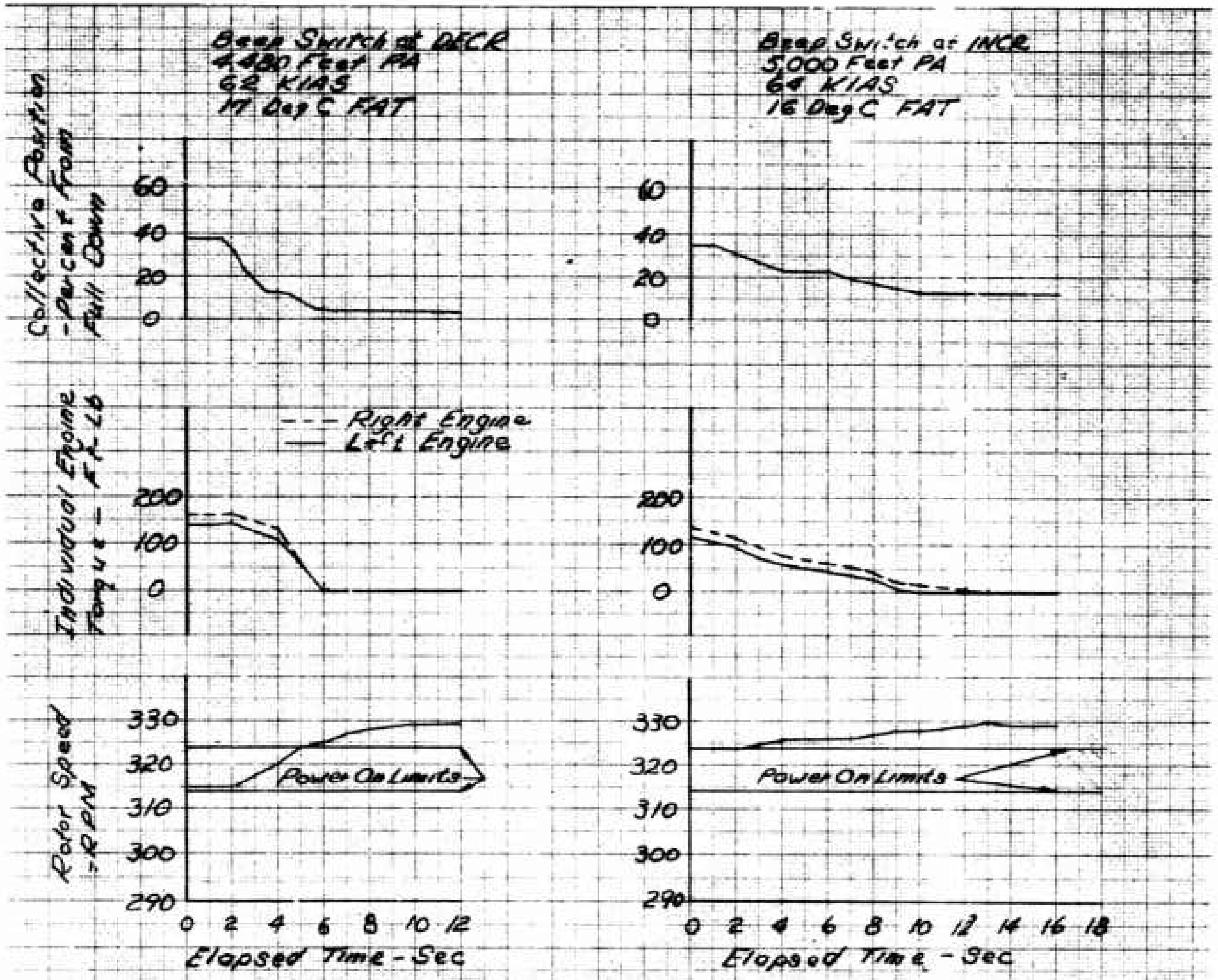


TIME HISTORIES OF DUAL-ENGINE TRANSIENTS —
COLLECTIVE PITCH CONTROL
Figure 6



DUAL-ENGINE TRANSIENT RESPONSE SUMMARY

Figure 7



TIME HISTORIES OF DUAL-ENGINE TRANSIENTS – COLLECTIVE PITCH CONTROL

Figure 8

Operational Analysis

The N_f governor was considered inadequate with respect to rotor overspeed. During approaches where N_f was beeped to 100 percent prior to commencing a landing approach, N_f overshoot to 103 percent and above was common, and beep switch response was too slow to compensate. As a result, considerable throttle manipulation was required. This situation was most noticeable in cases where quick minimum collective pitch control settings were required during an accompanying aircraft flare. Overshoot was distracting and added to the pilot workload. Rotor droop or undershoot resulting from increased torque demand was acceptable.

Dual-Engine Transients - Throttle Retardations.

Test Description

Dual-engine transients were induced by rapidly (one-half second) retarding both throttles to the flight idle position for the test conditions shown in table V. Test procedures were as follows:

1. The aircraft was stabilized at the test altitude and airspeed and the rotor speed adjusted to 100-percent rpm. The throttles were full open and torque was as required for level flight.

2. Both throttles were rapidly retarded to the flight idle position in about one-half second. As rotor speed dropped rapidly, the collective pitch control was lowered to restore rotor speed and engine power was then restored as required to recover normal flight.

3. Data were recorded throughout the above maneuvers.

Functional Analysis

Figure 9 presents typical time histories of several of these tests. The primary characteristic of dual-engine throttle retardations was, as expected, rapid decay in rotor speed. Depending on pilot technique, the collective pitch control could be held at a fixed position for one-half to one and one-half seconds before rotor speed began to decay rapidly. Lowering of the collective pitch control was then mandatory to maintain rotor speed at a safe level. Some pilot anticipation was involved since the pilot knew he was going to lose power. Rotor speed decayed to less than the minimum allowable power-on transient limit of 294 rpm in less than 4 seconds.

No engine problems such as deceleration stalls, rpm hangups, or undershoot of engine parameters were experienced and no detrimental effects of these tests were noted. The effects of bleed air extraction were not detectable during these tests.

Operational Analysis

Rotor speed decay was considered typical of the H-1 model helicopter. A tendency for nosedown pitch was evident, but was easily corrected. Full control capability was maintained.

Table V

SUMMARY OF TEST CONDITIONS,
DUAL-ENGINE TRANSIENTS
- THROTTLE RETARDS

Pressure Altitude (ft)	Airspeed (KIAS)	Bleed Air Condition
5,000	67	ON
5,000	30	ON
5,000	30	OFF
5,150	68	OFF
5,200	90	ON
5,200	90	OFF
9,700	25	OFF
9,700	25	ON
9,700	60	OFF
9,700	60	ON
9,700	90	OFF
9,700	90	ON
12,800	72	OFF
14,800	29	ON

Single-Engine Transients - Collective Pitch Control.

Test Description

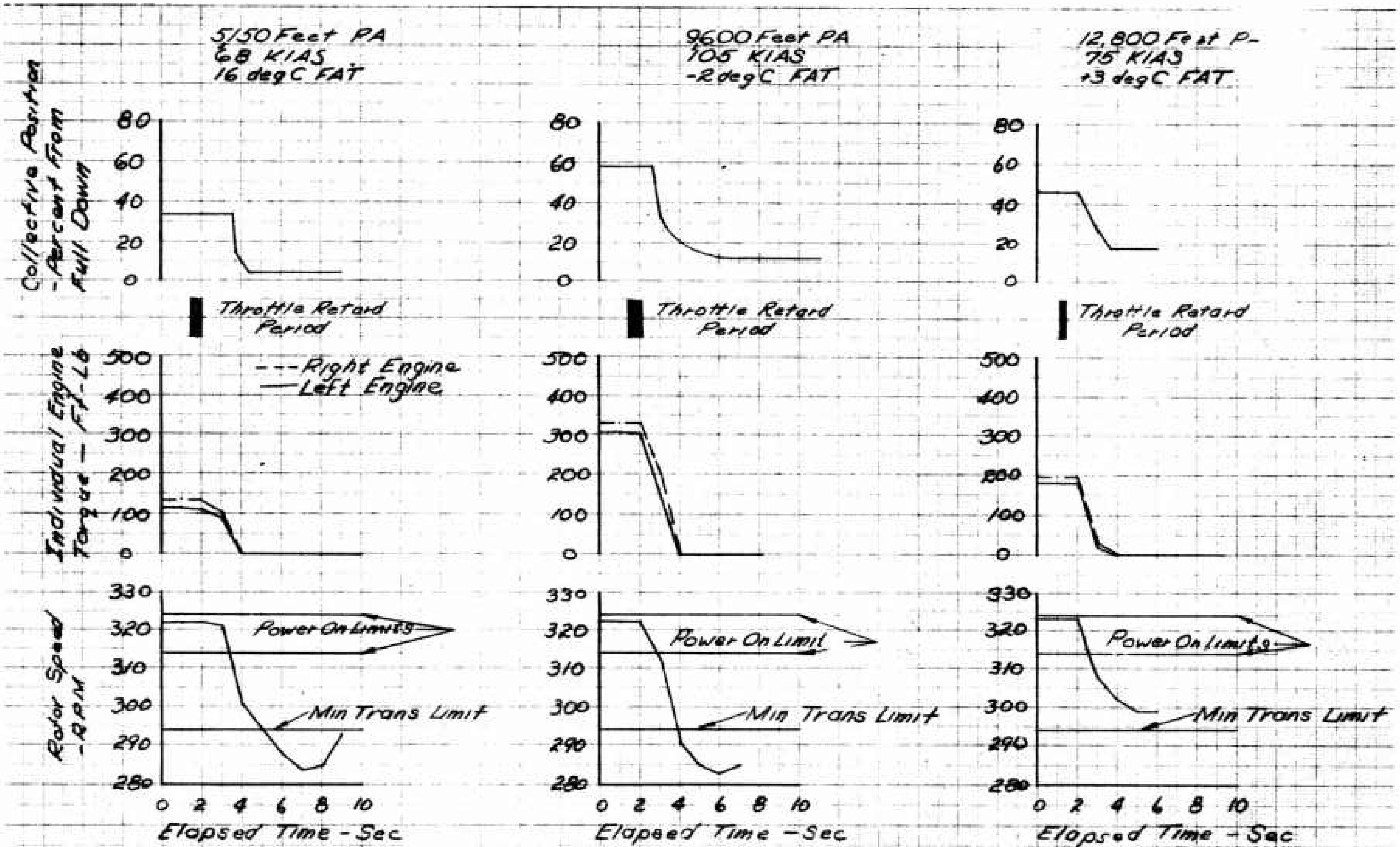
Single-engine transients induced by raising the collective pitch control were performed at the test conditions shown in table VI. The test procedure was as follows:

1. One engine throttle was retarded to flight idle and the aircraft was stabilized at the test altitude and airspeed. Rotor speed was adjusted to 100 percent and rotor torque was as required for level flight. The collective pitch control position was noted.

2. The collective pitch control was lowered at a rate to prevent exceeding any limits (primarily maximum power-on rotor speed limit of 104.5 percent) to achieve approximately 20-percent indicated torque. The propulsion system was allowed to stabilize.

3. The collective pitch control was raised at varying rates to approximately the level started at in step 1 above. Propulsion system parameters were allowed to stabilize.

4. Data were recorded throughout the above maneuvers.



TIME HISTORIES OF DUAL-ENGINE TRANSIENTS - THROTTLE RETARDS

Figure 9

Functional Analysis

Figures 10 through 12 present time histories of N_R, engine torque, and collective pitch control position on some of the transients performed. Engine acceleration time and transient rotor droop recovery time were acceptable. No engine parameters approached specification limits during any of the transients and no compressor stalls, rpm hangups, or ITT over-temperature conditions were experienced. No overshoot in torque was evident.

Figure 13 presents the relationship between torque demand rate and minimum transient rotor speed. Under no circumstances did rotor speed ever drop below the allowable minimum transient speed of 294 rpm. Data scatter shown in figure 13 was attributed to variation in pilot technique and variation in rotor speed at the beginning of each test (328 to 330 rpm). In spite of these variations, the trend of lower minimum transient rotor speed with increased torque demand rate was clearly indicated. Engine acceleration and transient rotor droop characteristics during single-engine transients induced by movement of the collective pitch control were acceptable.

Operational Analysis

In cases where torque required for level flight did not exceed the maximum available single engine torque, engine acceleration was sufficient to minimize rotor speed transient droop. Where torque demands exceeded the single engine maximum available torque, the rate of N_R decay was gradual enough to allow effective compensation by using reduced collective pitch.

Single-Engine Transients - Throttle Retardations.

Test Description

Single-engine failures were simulated at the flight conditions shown in table VII. Test procedures used were as follows:

1. The aircraft was stabilized at the test altitude and airspeed. Rotor speed was adjusted to between 321 and 322 rpm, and both engines were at full throttle.

2. One throttle was rapidly retarded (one-half second) to flight idle with the collective pitch control held in the original position.

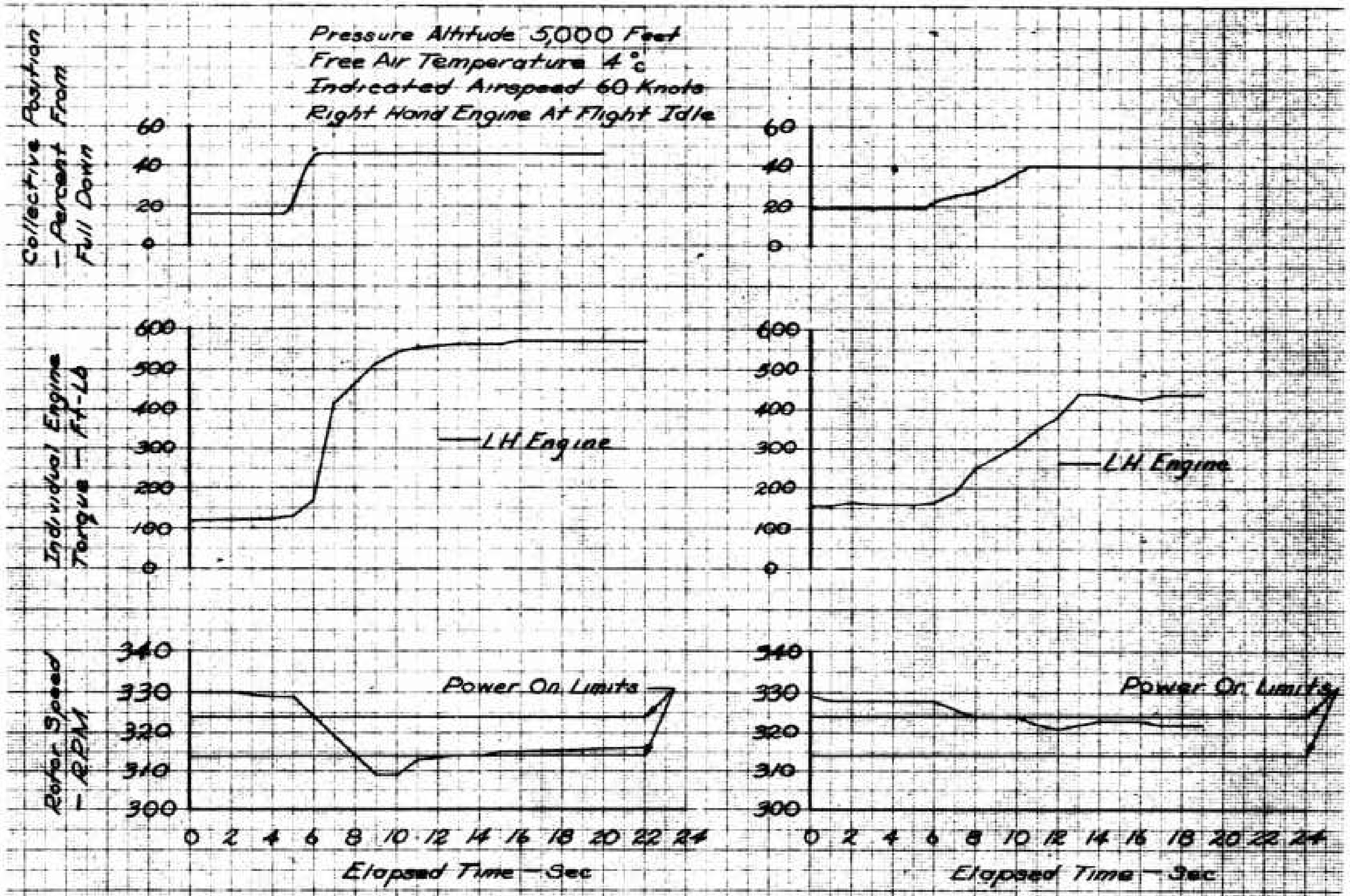
3. If rotor speed did not decay below 91 percent, the system was allowed to stabilize.

4. If rotor speed decayed below 91 percent, rotor speed was recovered as required by lowering the collective pitch control.

Table VI

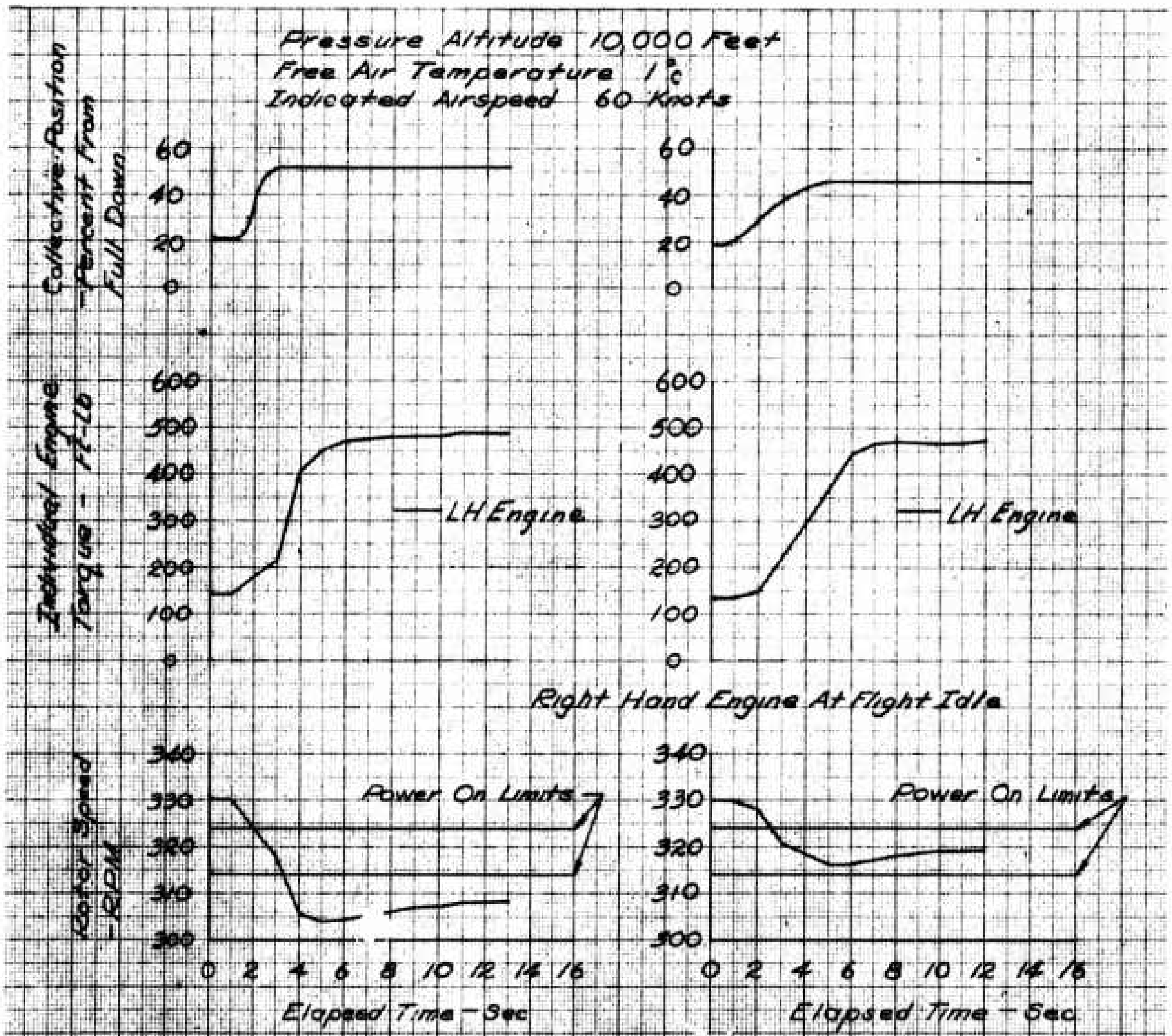
SUMMARY OF TEST CONDITIONS,
SINGLE-ENGINE TRANSIENTS - COLLECTIVE
PITCH CONTROL

Pressure Altitude (ft)	Airspeed (KIAS)	Target Collective Movement Duration (sec)
4,250	10	1
4,350	10	3
4,500	22	2
4,820	56	5
4,880	63	2
4,900	58	2
5,130	67	2
8,680	69	2
8,980	70	1
8,500	25	1
8,600	20	2
9,000	58	3
9,250	62	1
13,100	68	2
13,100	68	1
14,620	28	1
14,700	30	3



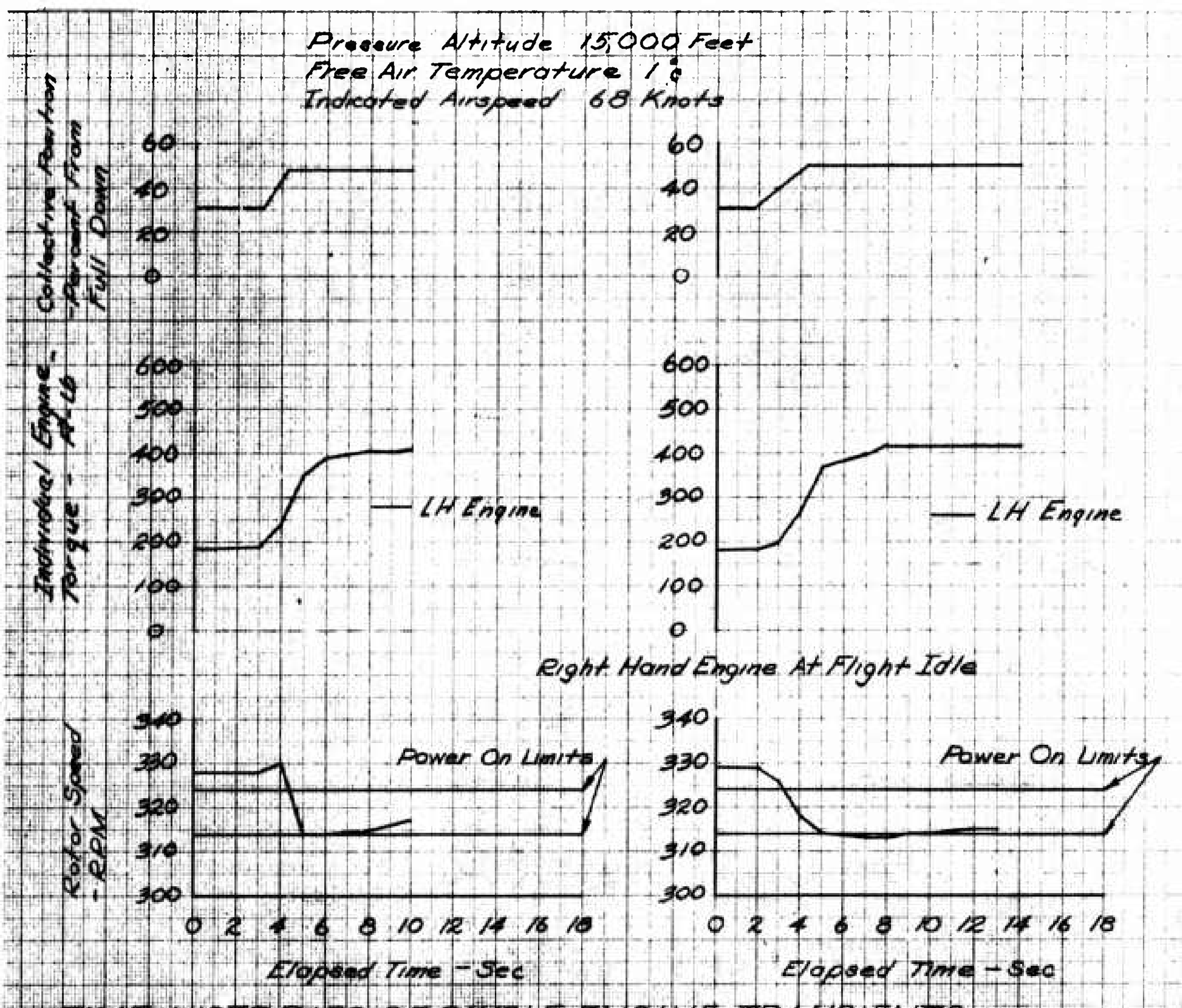
TIME HISTORIES OF SINGLE-ENGINE TRANSIENTS — COLLECTIVE PITCH CONTROL

Figure 10



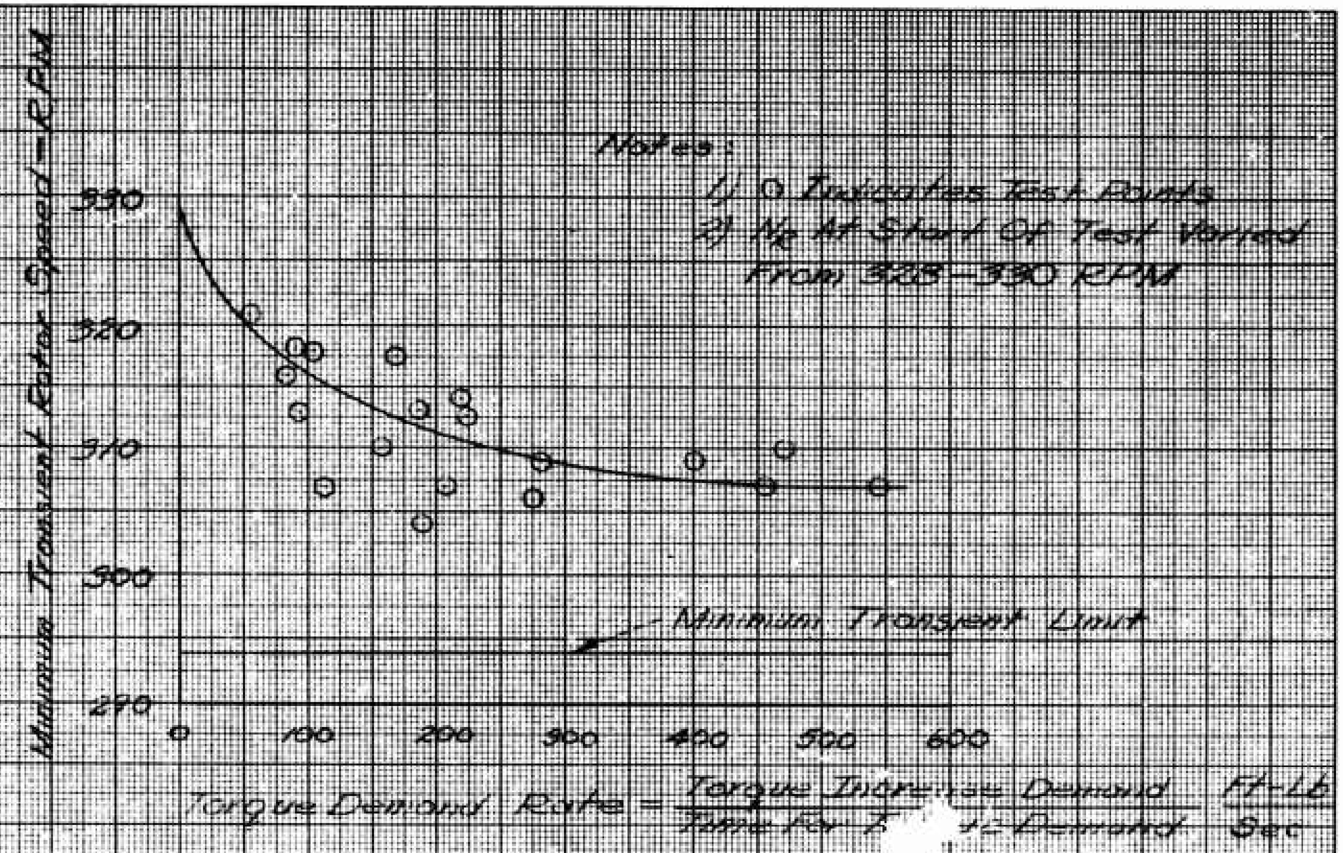
TIME HISTORIES OF SINGLE-ENGINE TRANSIENTS — COLLECTIVE PITCH CONTROL

Figure 11



TIME HISTORIES OF SINGLE-ENGINE TRANSIENTS — COLLECTIVE PITCH CONTROL

Figure 12



SINGLE-ENGINE TRANSIENT RESPONSE SUMMARY

Figure 13

Table VII

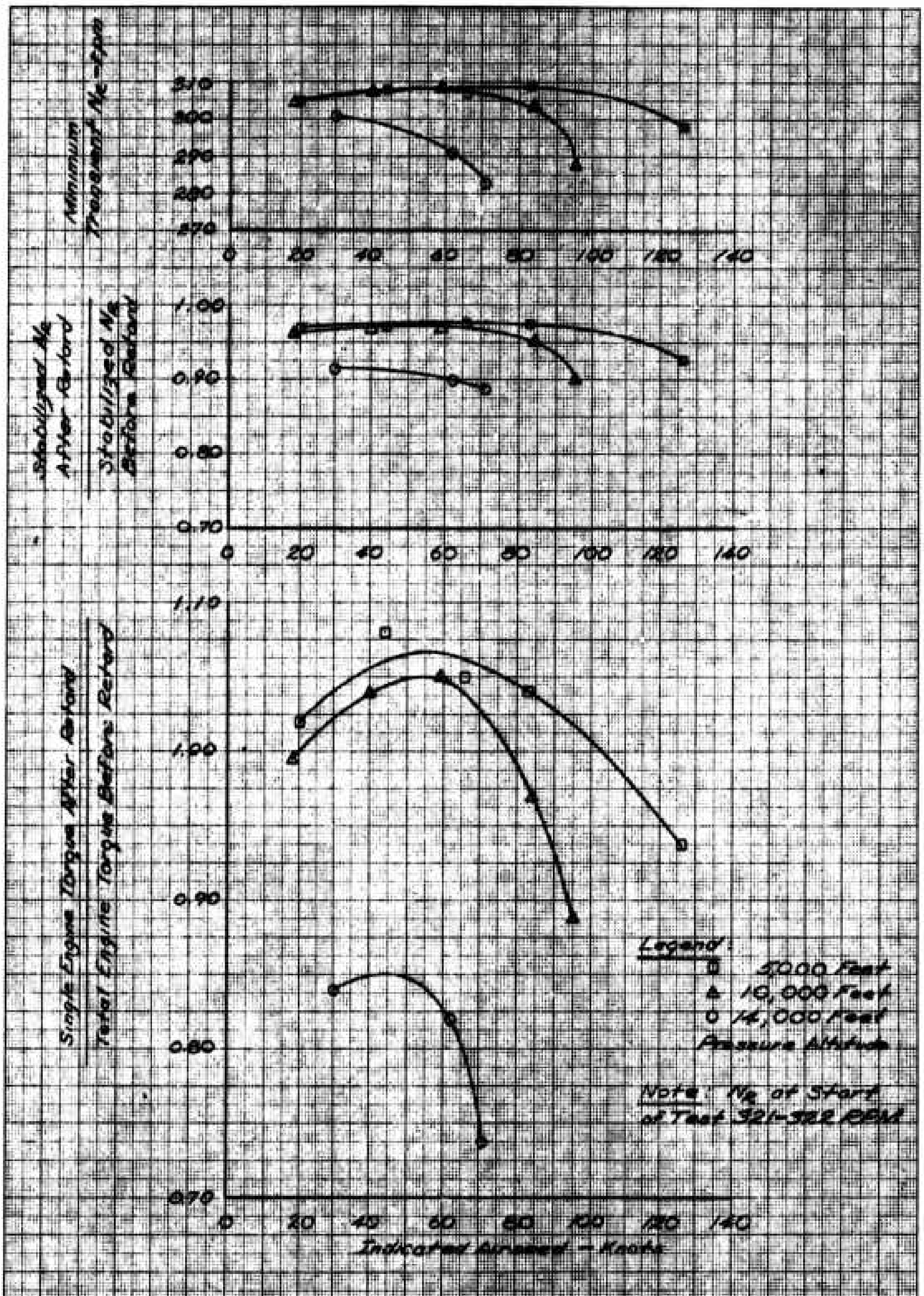
SUMMARY OF TEST CONDITIONS,

SINGLE-ENGINE TRANSIENTS - THROTTLE RETARDS

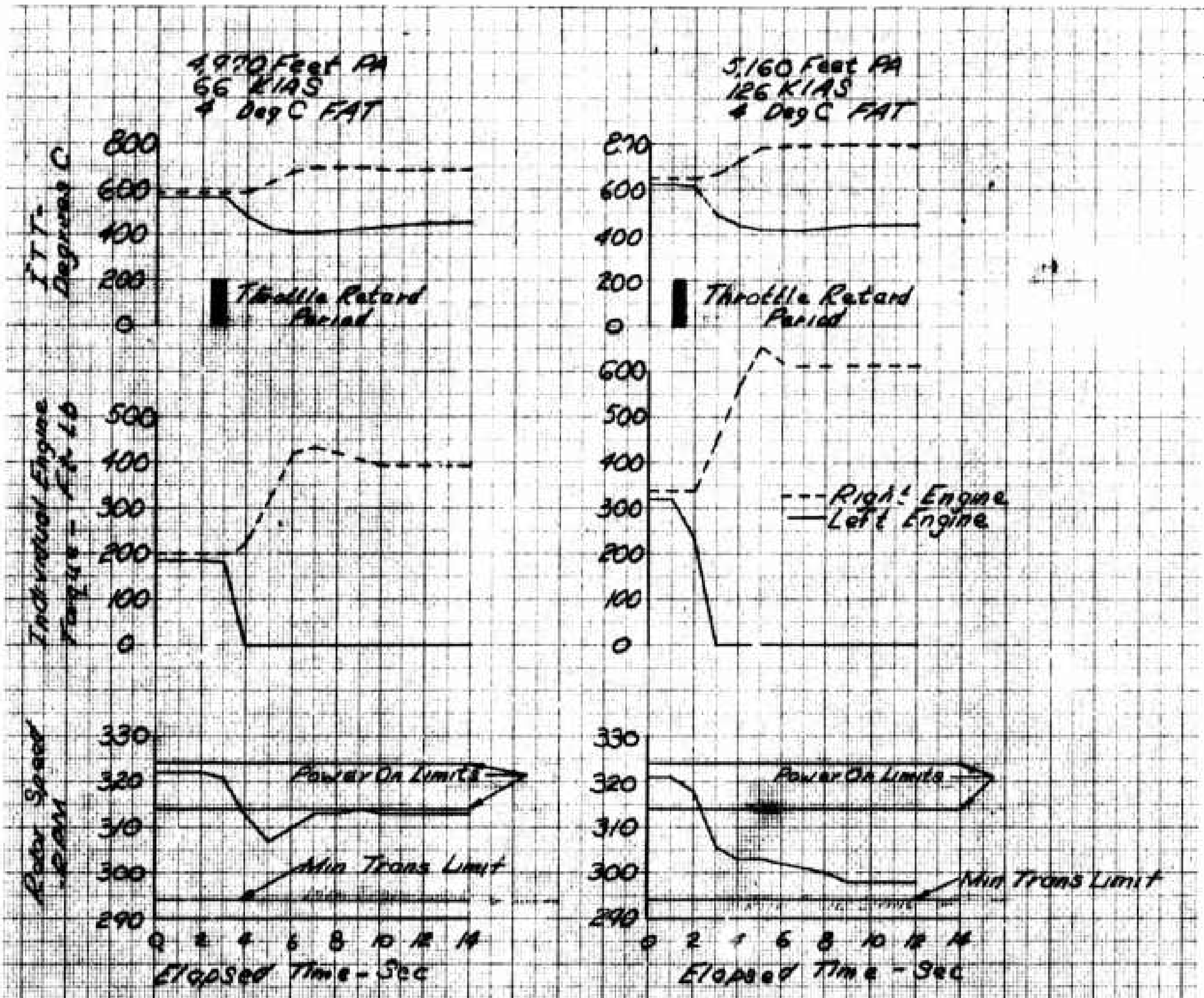
Pressure Altitude (ft)	Airspeed (KIAS)	Bleed Air Condition
5,000	20	OFF
5,000	40	OFF
5,000	60	OFF
5,000	67	ON
5,000	80	OFF
5,000	100	OFF
5,150	68	OFF
9,480	95	OFF
9,500	59	OFF
9,530	84	OFF
9,620	18	OFF
9,850	40	OFF
10,000	40	OFF
13,800	65	OFF
13,900	30	OFF
13,940	71	OFF
19,870	50	ON
20,150	61	OFF
20,680	48	OFF
20,680	65	ON

Functional Analysis

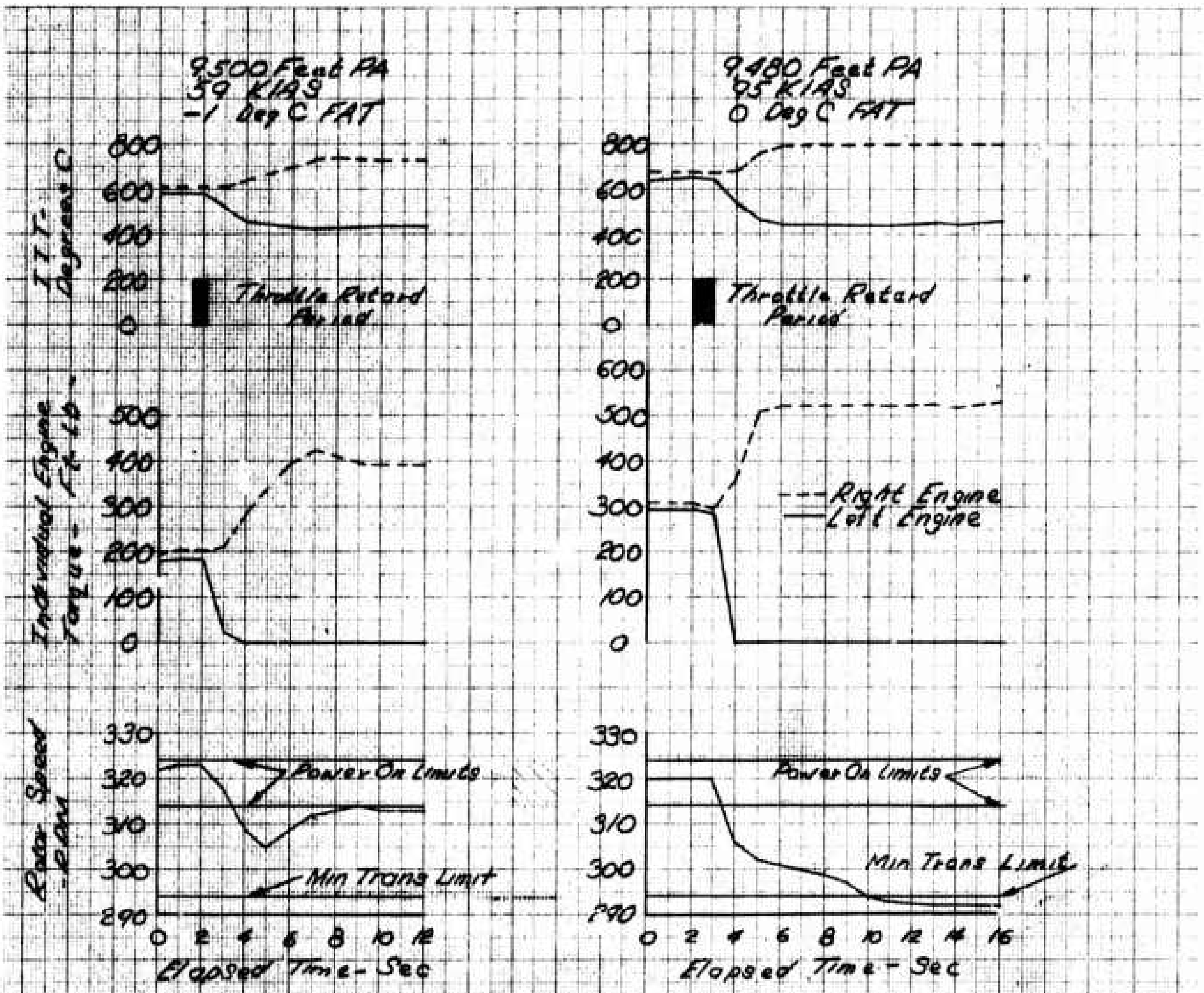
Figure 14 presents a summary of propulsion system recovery indices which compares dual engine operation before a throttle retard with single-engine operation after the throttle retard. Minimum rotor speed during the transition from dual to single-engine operation is also shown. Single-engine recovery was excellent at 5,000 and 10,000 feet PA between 20 and 75 KIAS. Single-engine torque was higher than the dual engine torque, N_R recovery was better than 0.95, and the minimum transient N_R was above the minimum transient limit of 294 rpm. Only above 90 KIAS at 10,000 feet PA did the transient N_R decay below 294 rpm and the torque and N_R recovery indices decreased to below 0.90. This was due to engine topping power being reached on the single engine which limited the amount of power deliverable to the rotor. Figures 15 and 16 present time histories of engine parameters during typical throttle retardations at 5,000 feet PA and 10,000 feet PA, respectively.



RECOVERY INDICIES —
SINGLE-ENGINE THROTTLE RETARDS
Figure 14



TIME HISTORIES OF SINGLE-ENGINE TRANSIENTS-
THROTTLE RETARDS
Figure 15



TIME HISTORIES OF SINGLE-ENGINE TRANSIENTS - THROTTLE RETARDS

Figure 16

At approximately 14,000 feet PA, single-engine operation was not possible after a rapid throttle retard. Transient rotor speed decayed to below 294 rpm, stabilized N_R recovery was about 0.90, and torque recovery was about 0.80. This was again due to engine topping power being reached at the test conditions.

Four tests performed at approximately 20,000 feet PA resulted in minimum transient rotor speeds so low that lowering of the collective pitch control was necessary to recover rotor speed to a safe level before stabilized conditions could be achieved. Single-engine operation at this altitude could not be maintained.

Minor engine torque oscillations were noted during two throttle retardations at 10,000 feet pressure altitude and 40 KIAS. The oscillations occurred on the engine that was assuming the load transferred to it by the loss of torque on the other engine. A repeat test on both engines on a subsequent flight produced no oscillations.

It was not the intent of these tests to determine the single-engine operating envelope of the UH-1N. The tests did demonstrate that simulated single-engine failures presented no unusual problem either during the transient or after stabilized conditions were achieved.

Operational Analysis

The aircraft exhibited a slight, but easily controllable yaw. No unusual problems were evident from a pilot standpoint.

Beep Switch Authority.

Test Description

The beep switch was designed to adjust N_f, which in turn determined N_R, between 97- and 102.5-percent rpm. Rotor speed change available with use of the beep switch was evaluated on the ground and in flight at 5,300 feet PA and 65 KIAS. Test procedures were as follows:

1. The test altitude and airspeed or ground static conditions were attained.

2. Rotor speed was adjusted to approximately 314 rpm with beep at minimum DECR.

3. The beep switch was placed to INCR until rotor speed stabilized.

4. The beep switch was then placed to DECR until rotor rpm stabilized.

5. Data were recorded continuously throughout the test, and the collective pitch control and engine throttles were held at constant positions.

Functional Analysis

Time histories of N_R and N_f during increasing and decreasing beeps are shown in figure 17. Results of both the ground test and flight test were similar. The beep switch permitted an N_f change from 96.8- to 102.5-

percent rpm on the ground, and from 97.8- to 103.3-percent rpm at 5,300 feet PA, 65 KIAS. This beep authority was acceptable. However, a dead band existed when changing from INCR to DECR or DECR to INCR. This dead band resulted in a rotor speed change delay of from one to one and one half seconds. In addition, N_f overshoot occurred when INCR was actuated with the rotor speed at minimum. This overshoot in N_f resulted in rotor overspeed as much as 9 rpm above the normal power-on limit of 324 rpm. The N_f governor response to beep switch actuation in INCR should be redesigned to eliminate the overshoot in rotor speed. (R 10)

Compressor Bleed Air Extraction Effects.

Test Description

Tests to determine the effects of bleed air extraction (heating and defogging) on engine parameters were performed at the test conditions shown in table VIII. The test procedure used was as follows:

1. The aircraft was stabilized at the test conditions with the bleed air on. Data were recorded.

2. The bleed air was turned off and the engines allowed to stabilize. Data were recorded.

3. The bleed air was turned on and the engines allowed to stabilize. Data were recorded.

Functional Analysis

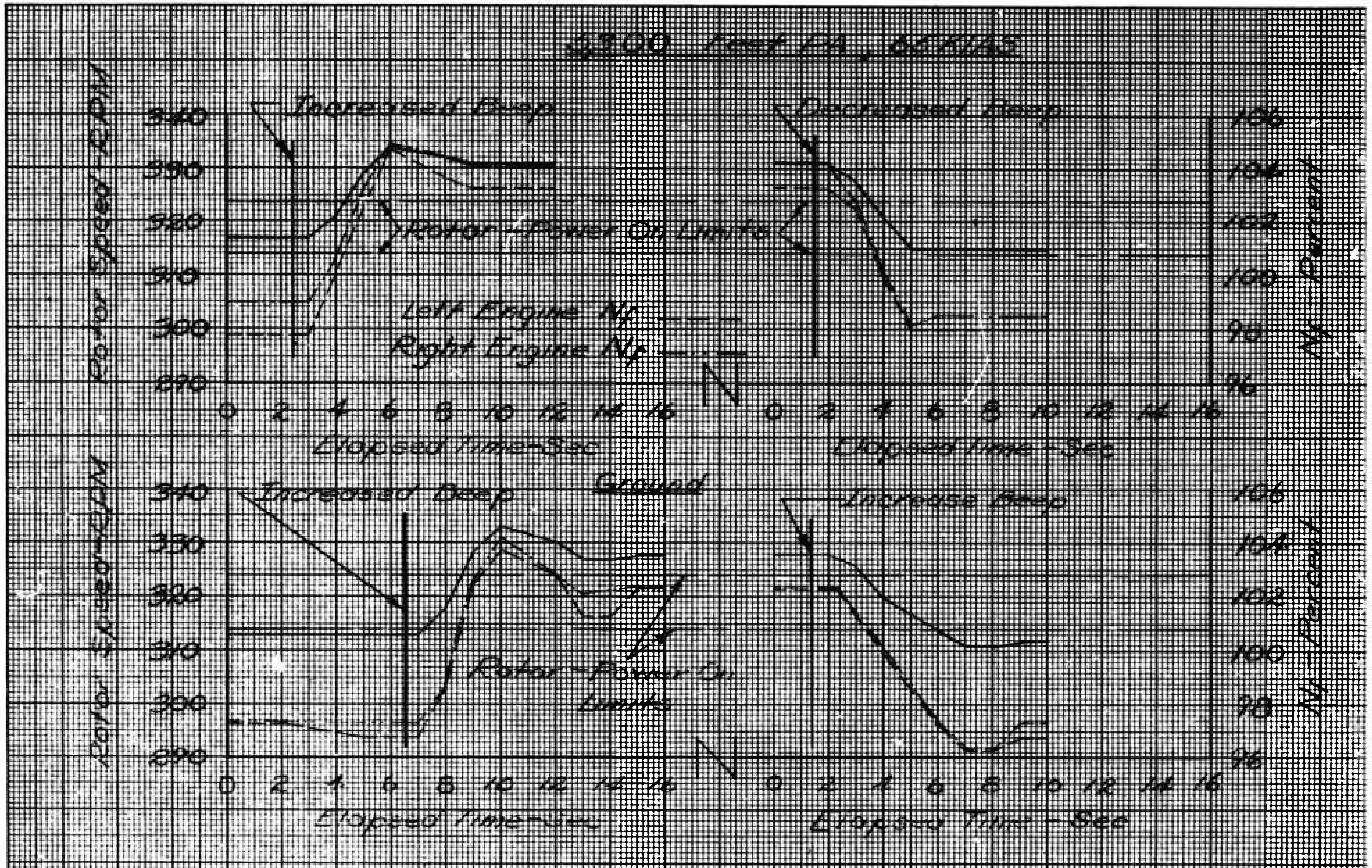
Results of engine bleed air extraction tests are also presented in table VIII. Changes in ITT and N_g demonstrated no particular trends and were small enough in magnitude to be insignificant. Bleed air extraction effects on steady state engine operation were acceptable.

Overall System Analysis

The general comments in this section are presented to identify specific problem areas observed by the pilot.

Power Turbine Governor Response.

The torque control unit and engine combination caused steady state torque oscillations that were annoying at high power settings. The magnitude of these oscillations was about ± 2 to ± 3 percent torque at high power settings. This magnitude was too low to be reflected in N_f, N_R, ITT, or N_g. The oscillations were manifested by a lateral vibration in some cases and a continuous pulsating yaw in others. This phenomena, although of a lesser magnitude, created a constant annoying oscillation at cruise power settings. The problem was especially apparent during aerial gunnery (reference 3).



TIME HISTORIES OF BEEP SWITCH ACTUATION
Figure 17

Table VIII

ENGINE BLEED EFFECTS

Test Conditions			Results			
			Engine ITT (deg C)		Engine N_g (pct)	
Pressure Altitude (ft)	Airspeed (KIAS)	Bleed Condition	No. 1	No. 2	No. 1	No. 2
5,050	66	ON	605	632	85.7	85.2
		OFF	578	608	85.7	85.2
		ON	575	610	85.0	85.0
10,410	69	ON	582	612	87.3	86.4
		OFF	582	615	87.3	86.4
		ON	582	615	87.3	86.4
15,100	65	ON	592	630	87.9	87.1
		OFF	585	623	88.3	87.4
		ON	580	625	88.3	87.4

Governor response to N_f changes induced by flight gusts caused overshoots in N_R which were not well damped. The result required resetting the tail rotor pitch which itself produced another sequence of N_f tail rotor-yaw changes. As a consequence, directional control was demanding of the pilot and became very burdensome in turbulence as the governor attempted to follow load changes in the system.

These two problems, torque fluctuations and directional control in turbulence were related to N_f governor response. An investigation should be conducted to further define these problems and appropriate redesign should be accomplished. **(R 11)**

Engine Limiter Functions.

Engine technical data (references 5 and 9) presented minimum torque allowable at topping power as a function of ambient temperature and pressure altitude, but included no reference to ITT and N_g at the same ambient conditions. The engine was not expected to top in power with the same values of ITT and N_g as ambient temperature changed. Thus, the pilot was given only a portion of the information required to analyze engine conditions and performance. The Flight Manual should be revised to include minimum allowable topping values of ITT and N_g as a function of ambient temperature as well as a minimum acceptable topping torque. This minimum acceptable torque should be based on the lower limit of ITT and N_g topping values. **(R 12)**

Engine Deterioration.

Deterioration in engine performance can be expected to occur during operational usage. No provisions were made for monitoring engine deterioration on the UH-1N aircraft. A procedure for monitoring engine performance during operational usage should be developed, based on the relationship between ITT and N_g. (R 13)

ITT Limiter and Bias System.

The limiter function of the ITT limiter and bias system presented both maintenance and operational problems. Maintenance troubleshooting of engine problems was made more difficult with this system installed. From a pilot standpoint, the limiter prevented intentional overtemperature when extra power was required in critical or combat conditions without pulling out the limiter/bias circuit breaker. The normal N_g governor would prevent gross overtemperatures and monitoring engine temperature limits is a normal pilot function. The bias portion of the system was satisfactory. The limiting portion of the ITT limiter/bias system should be deactivated. (R 14)

AGE Evaluation

Test results are contained in appendix II. Only those AGE items used during the Category II test program are listed. The majority of the AGE was satisfactory. UMR's were in process on those items that were not acceptable.

FUEL AND LUBRICATION SYSTEMS

General

System Description.

The fuel system included five fuel cells filled with fire suppression foam, submerged fuel pumps in two of the cells, shut-off valves, fuel quantity transmitters, a filler neck, fittings, fuel filler cap, airframe fuel filter, and controls. Two fuel cells were located below the cabin floor, two just aft of the cabin bulkhead, and one on the centerline below the service deck. Fuel interconnect lines connected all the cells. The two cells below the floor had fuel sump drains, fuel flow switches, jet pumps, and baffles. All cells were vented to the atmosphere. Electric motor-driven submerged fuel boost pumps were installed in the right and left main cells under the cabin floor.

The power plant lubrication system consisted of three separate sections, one for each engine and its related input portion of the combining gearbox, and one for the output portion of the combining gearbox. The lubricating system consisted of self-locking drain valves, system drains, oil coolers, thermal and pressure bypass valves, and oil cooler blowers. The three oil coolers were located within the engine cowling and were cooled by two fans powered by engine bleed air.

The transmission lubrication system was integral with the transmission. The oil pump was immersed in the oil sump. A thermal control bypass valve was installed in the transmission oil cooling system. The transmission included an oil filter with replaceable filter element. A detailed description of the system was given in reference 4.

Test Objectives.

The test objectives were:

1. To determine the accuracy of the fuel indicating systems.

2. To determine the adequacy of the fuel vent system.

3. To determine if the oil systems operated satisfactorily, maintained necessary oil pressure, and were free from oil leakage.

Ground Tests

Fuel Servicing and Defueling.

Test Description

Fuel servicing and defueling operations were monitored during maintenance activities throughout the test program.

Functional Analysis

Time required to fuel the aircraft with a full load of fuel averaged approximately five minutes. Defueling a full load of fuel required about three hours, because of a lack of a defueling connection. The normal method of defueling was through drain lines. This method was acceptable but did result in delayed maintenance on the fuel system when defueling was required.

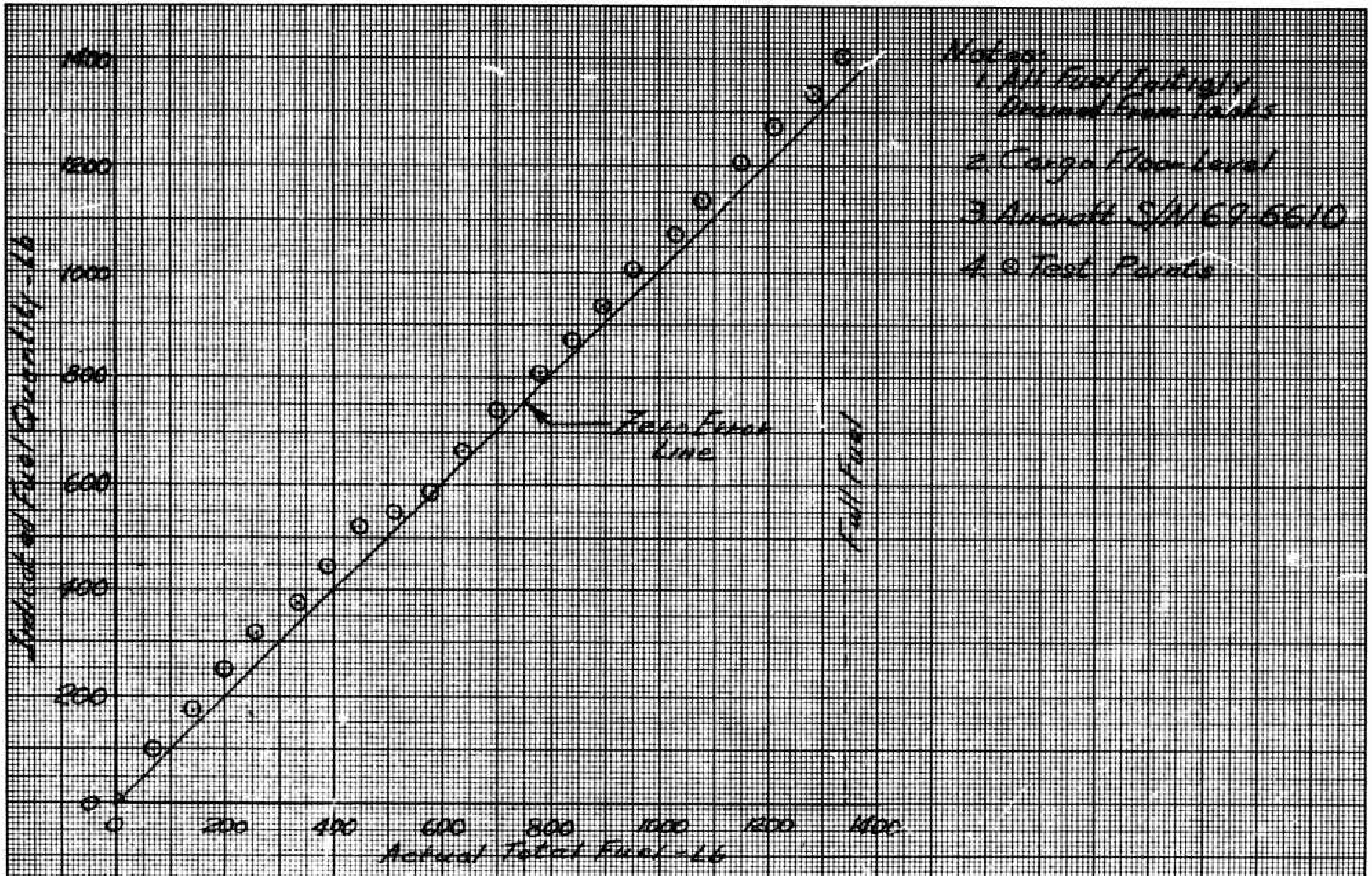
Fuel Quantity Indicating System Calibration.

Test Description

The aircraft was placed on a scale, defueled, drained, and leveled. Fuel quantity gauge readings and actual aircraft weight measurements were taken after each 10-gallon increment of fuel was added to the tanks. Approximately three to four minutes elapsed between successive readings.

Functional Analysis

Data presented in figure 18 indicate that the gauge accuracy was approximately linear, indicating about 30 pounds (4.7 gallons) above actual weight. Irregularities during the first 600 pounds of fuel added were probably due to the fuel settling characteristics through the foam--filled tanks (from top to bottom). A total of 210 gallons was added with the aircraft in a level attitude on jacks. About 1 gallon was vented



FUEL QUANTITY SYSTEM CALIBRATION

Figure 18

overboard when the aircraft was lowered to the normal nose-high attitude while resting on the landing skids. This fuel venting occurred consistently after normal fueling operation, but presented no particular problem. The fuel indicating system was satisfactory.

Flight Tests

Simulated Fuel Tank Boost Pump Failure.

Test Description

Only one specific test was performed on the fuel system. Engines were set at military rated power, the left-hand fuel tank boost pump was deactivated by pulling the circuit breaker, the fuel crossfeed valve was closed, and a climb performed from 2,300 to 20,000 feet PA. The test was performed on both aircraft S/N 69-6610 and S/N 68-10776.

Functional Analysis

On aircraft S/N 69-6610, minor torque fluctuations were noted on the left-hand engine between 12,000 and 14,000 feet PA, but they disappeared and no further discrepancies were noted. The test was repeated on aircraft S/N 68-10776, and no discrepancies were noted. Throughout the Category II test program, the fuel and lubrication systems were operationally and functionally satisfactory.

Overall System Analysis:

The fuel system did not have a means to isolate under-the-floor tanks in the event of combat damage to a tank. The fuel system should be redesigned to incorporate tank isolation in the event of combat damage. (R 15)

The fuel system was not crashworthy (reference 10) and Army accident statistics (reference 11) indicate a vastly superior survival rate for personnel involved in H-1 series accidents with a crashworthy fuel system. The fuel system should be redesigned to provide a crashworthy system. (R 16)

DRIVE AND TRANSMISSION COMPONENTS

General

System Description.

The drive system that transmitted power from the engines to the rotors included the main transmission, free-wheeling unit, tail rotor driveshafting, and the 42- and 90-degree gearboxes.

The UH-1N used a new improved main gearbox rated at 1,250 shaft horsepower for 5 minutes. The accessories that were driven by the transmission included the lubrication pump, tachometer generator, and the hydraulic pump for the flight controls. The transmission supported the rotating controls for the main rotor, and was mounted to the airframe by five rubber mounts, four dampers, and a lift link.

The transmission system consisted of a single-stage bevel gear unit, a two-stage planetary gear system, and a tail rotor drive system. The transmission included all parts used in the transmission of power from the power plant to the tail rotor through shaft assemblies and to the main rotor through the mast assembly. The 42-degree intermediate gearbox transmitted power from the tail boom shafts to the rear shaft. The 90-degree gearbox transmitted power from the rear shaft to the tail rotor shaft. Splash lubrication was employed in both the 42-degree and 90-degree gearboxes. A rotor brake was provided which was manually actuated from the cockpit. A detailed description of the system was given in reference 4.

Test Objectives.

Specific test objectives were:

1. To determine the functional adequacy of the 42-degree and 90-degree gearboxes.

2. To determine the functional adequacy of the rotor brake.

3. To evaluate accessibility and ease of servicing all components in this system.

Ground and Flight Tests

Test Description.

No specific tests were performed to evaluate the transmission and drive components. Operation and adequacy of these components were monitored continuously throughout the Category II program. All systems were used according to Flight Manual instructions. The rotor brake was used on essentially all engine shut-downs.

Functional Analysis.

The transmission and drive components operated satisfactorily throughout the Category II test program. No maintenance actions, other than routine, were required. Accessibility and ease of servicing of all components was satisfactory.

AGE Evaluation

Test results are contained in appendix II. Only those AGE items used during the Category II program are listed. All AGE was satisfactory.

CONCLUSIONS AND RECOMMENDATIONS

OVERALL

The propulsion system as installed and tested in the UH-1N helicopter was adequate for accomplishment of mission objectives. Conclusions and recommendations reached as a result of tests performed during the Air Force Preliminary Evaluation, but not repeated during the Category II program were still valid.

1. The recommendations developed during the AFPE that are still outstanding should be implemented (page 3).

Some deficiencies reported in Unsatisfactory Materiel Reports were not corrected as of the end of the Category II testing.

2. Those deficiencies documented in UMR's that are still open for action should be corrected (page 3).

POWER PLANT

Ground engine starts using either battery power or generator power were satisfactory. Engine airstarts performed in various system modes throughout the flight envelope were satisfactory. Dual- and single-engine static droop characteristics were acceptable. Engine acceleration and rotor droop characteristics during dual- and single-engine transients induced by raising of the collective stick were satisfactory. Engine characteristics during rapid throttle retardations were satisfactory both with dual- and single-engine operation. Bleed air extrac- effects on steady state engine operation were acceptable. The majority of the AGE was satisfactory.

During engine starts, the process of turning the generator switch to OFF produced a needless switch action. Manual deactivation of the starter switch was frequently omitted and the design increased the chance of inadvertently leaving the starter switch engaged.

3. The Flight Manual should be revised to delete the required action of turning the generator switch to OFF prior to engine start (page 10).

4. The starter switch should be redesigned to incorporate an automatic deactivation feature (page 10).

The functional adequacy of the manual fuel control was satisfactory. The Flight Manual contained no reference to expected N_g speed change when switching from automatic to manual fuel control. The engines exhibited a characteristic "blurp" noise when switchovers were accomplished. Close proximity of the FUEL CONT switches to other switches on the ENGINE AND FUEL CONTROL PANEL and indistinct labeling of the switches made fuel control switchovers disconcerting to the pilots.

5. The Flight Manual should be revised to incorporate a NOTE similar to that contained in T.O. 1H-1(U)N-2-2 which stated that switchover from automatic to manual fuel control should result in a rise in N_g of 4 percent at sea level and 2 percent additional rpm for each 1,000 feet of pressure altitude increase (page 12).

6. The Flight Manual should be revised to incorporate a NOTE that a characteristic "blurp" noise during fuel control switchover is normal (page 12).

7. The FUEL CONT switches should be labeled more clearly, preferably on top of the switch itself (page 12).

Though not demonstrated by actual test, data indicated that it was possible for engine overtorquing to occur during rapid upward movements of the collective pitch control to high settings.

8. A CAUTION should be added to the Flight Manual stating that this type of collective pitch control movement should be avoided (page 17).

Rotor speed compensation characteristics were inadequate to maintain rotor speed within power on limits when the collective pitch control was lowered even when minimum beep was applied.

9. Rotor speed compensation should be improved to prevent rotor overspeed during engine transients induced by lowering of the collective pitch control (pages 17).

Rotor overspeed above the maximum allowable power on limit occurred when the beep switch was actuated to INCR with the rotor speed at minimum.

10. The N_f governor response to beep switch actuation in INCR should be redesigned to eliminate the overshoot in rotor speed (page 37).

Two problems, torque fluctuation and directional control of the aircraft in turbulence, were related to N_f governor response.

11. An investigation should be conducted to further define these problems and appropriate redesign should be accomplished (page 39).

Engine technical data presented minimum torque allowable at topping power as a function of ambient temperature and pressure altitude, but included no reference to ITT and N_g at the same ambient conditions.

12. The Flight Manual should be revised to include minimum allowable topping values of ITT and N_g as well as minimum allowable torque. This minimum acceptable torque should be based on the lower limit of ITT and N_g topping values (page 39).

No provisions were made for analyzing engine deterioration on the UH-1N helicopter.

13. A procedure for monitoring engine performance during operational usage should be developed, based on the relationship between ITT and N_g (page 40).

The limiter function of the ITT limiter/bias system presented maintenance servicing difficulties and also limited pilot flexibility in achieving full engine power in critical or combat situations. The bias portion of the system was satisfactory.

14. The limiting function of the ITT limiter/bias system should be deactivated (page 40).

FUEL AND LUBRICATION SYSTEMS

Throughout the Category II test program, the fuel and lubrication systems were functionally adequate. Fuel servicing of the aircraft was satisfactory. Defueling of the aircraft was acceptable, but time consuming. The fuel quantity indicating system and vent system were satisfactory. The fuel system did not have provisions to isolate under-the-floor tanks in the event of combat damage. The fuel system as designed was not crashworthy.

15. The fuel system should be redesigned to incorporate tank isolation in the event of combat damage to an under-the-floor tank (page 43).

16. The fuel system should be redesigned to provide a crashworthy system (page 43).

DRIVE AND TRANSMISSION COMPONENTS

Operation, functional adequacy, accessibility and ease of servicing of the drive and transmission components were satisfactory. All AGE was satisfactory.

APPENDIX I UNSATISFACTORY MATERIEL REPORT SUMMARY

UH-1N Aircraft S/N 68-10776 and 69-6610

UMR No.	Date	Description	Action Status
R70-905	8 Dec 70	Excessive manhours for cowl removal.	Closed.
R71-74	5 Feb 71	Automatic fuel control malfunction.	Still open.
R71-75	2 Feb 71	Exhaust duct cracks	Repair instructions incorporated in T.O. SEM No. UH-03-71-1.
R71-76	5 Feb 71	Improperly supported vent tube.	Closed.
R71-77	5 Feb 71	Bleed air valve oil leakage.	Still open.
R71-78	22 Feb 71	Transmission oil filter gasket failure.	ECP 547 has been issued-item closed.
R71-250	24 Mar 71	Main rotor blade grip seals leaking.	Still open.
R71-251	24 Mar 71	Combining gearbox seals leaking.	Still open.
R71-253	24 Mar 71	Oil level sight gauges inoperative.	Still open.
R71-81	24 Mar 71	Particle/air separator actuator failed.	Still open.
R71-84	24 Mar 71	Idle stop relay and solenoid failed.	Still open.
R71-259	4 May 71	Fuel tank boost pump pressure switch failure.	Still open.
R71-261	14 Jun 71	Transmission oil temperature indicator failure.	Still open.
R71-262	14 Jun 71	Transmission oil temperature bulb failure.	Closed.
R71-263	14 Jun 71	Transmission oil temperature thermo-switch failure.	Still open.
E71-349	18 Jun 71	Engine accessory gearbox jammed.	Still open,
R71-381	7 Jul 71	Power turbine governor failure	Still open.

APPENDIX II AGE EVALUATION

WUC	Part Number	Nomenclature	Use and Application	Remarks
Rotors and Flight Controls AGE, Main Rotor Hub and Blade Assembly T.O. 1H-1(U)N-2-1				
15000	T100220	Lifting slings	Attach main rotor to hoist for removal and installation.	Satisfactory
	T101330	Rigging fixture	Hold copilot cyclic stick centered for rigging cyclic and elevator controls.	Satisfactory
	T101356	Bench, buildup	Support main rotor for maintenance.	Satisfactory
	T101358 SWE126376	Wrench adapter Socket (alternate)	Remove and install main rotor retaining nut.	Satisfactory
	T101400	Support, scope	Align main rotor blades.	Satisfactory
	T101401	Scope, blade alignment	Align main rotor blades.	Satisfactory
	T101402	Grip positioning link	Prevent rotation of main rotor grip when pitch link is not installed	Satisfactory
	T101414	Wrench	Remove and install main rotor blade retaining bolt.	Satisfactory
	T101421	Plate, adapter	Support main rotor for maintenance.	Satisfactory
	T101468	Flap stop	Align main rotor trunnion for adjusting grip spacing and blade alignment.	Satisfactory
	7A050	Kit, propeller balancing	Balance main rotor and tail rotor.	Satisfactory
	7HEL054	Kit, balancing	Balance main rotor.	Satisfactory
	7HEL061	Kit, adapter	Balance main rotor.	Satisfactory
	7HEL074	Plate, squaring	Balance tail rotor.	Satisfactory
	7HEL153	Kit, small parts balancing	Balance tail rotor.	Satisfactory
Power Train AGE T.O. 1H-1(U)N-2-1				
26000	T100929	Jack screw set (5/16-24 NF)	Remove rotor brake quill.	Satisfactory
	T101308	Jack screw set (1/4-28 UNF)	Remove input drive quill. Remove hydraulic pump drive quill.	Satisfactory
	T101338	Jack screw set (5/16-18 UNC)	Remove tail rotor drive quill. Remove 42-degree gearbox quill.	Satisfactory
Miscellaneous AGE				
22000	3000B	Trailer, transportation	To provide mounting for engine assembly.	Satisfactory
26000	204-040-929-29	Cover lift plate	To provide lifting provision for transmission.	Satisfactory
15000	PD 2659	Socket	To remove or torque main rotor mast nut.	Satisfactory
01320	314150	Nozzle	To lubricate midget flush type fittings.	UMR in process
22000	SWE 13833	Sling assembly	To lift complete engine assembly.	UMR in process
22000	SWE 13852-406	Kit, rail adapter assembly	To provide mounting for engine assembly.	Satisfactory
15000	T101493	Wrench	To remove or torque the collective hub retaining nut.	Satisfactory
22000	T101579	Alignment tool	To check alignment of the engine drive shaft with the transmission.	Satisfactory

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13. ABSTRACT

This report presents the results of the propulsion system evaluation conducted during the UH-1N Category II systems evaluation program. The propulsion system was adequate for accomplishment of mission objectives, but several improvements should be made. Flight Manual changes were considered necessary for engine starting, manual fuel control operation, engine topping parameters, and engine deterioration. Rotor overspeed occurred when the beep switch was actuated to increase rotor speed and when the collective pitch control was lowered. The fuel system should be redesigned to provide tank isolation in the event of combat damage. The fuel system should also be crashworthy. Operation, functional adequacy, accessibility, and ease of servicing of the drive and transmission components were acceptable.

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